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NEW SERIES
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Single copies 50 cents

To be ready for fall use—

MECHANICS OF MATERIALS

By PHILIP G. LAURSON, *Associate Professor of Engineering Mechanics,* and WILLIAM J. COX, *Assistant Professor of Engineering Mechanics; both at Yale University*

This new book is designed for courses in mechanics of materials as offered in the undergraduate engineering curriculum. The essentials of the subject are covered logically and thoroughly in the first fifteen chapters. The remaining eight chapters contain slightly more advanced or more specialized material, any part of which may be omitted. Thus a maximum of flexibility is obtained. The material is presented in a form easily grasped by students. The authors take particular care to express statements clearly and with simple explanations.

The physical behavior of stressed bodies has been emphasized, as well as the mathematical expression of this behavior. Throughout the book the authors have endeavored never to lose sight of the fact that the ultimate purpose of a course in mechanics of materials is to prepare the student for an eventual clear understanding of machine and structural design. From the beginning, therefore, the student is encouraged to think of the realities of the situations with which he is being called on to deal. Unusual attention has been given to outlining the bases from which allowable stresses are determined, and the effort has been made to habituate the student to consider whether the unit stresses he encounters in problems and illustrative examples are or are not suitable. A feature of the book is the inclusion of nearly five hundred carefully designed problems, properly graded as to difficulty.

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46th Annual Meeting, A. & M. College of Texas, College Station, Texas, June 27–30, 1938

"Suppose I get sick? After all, I'm only human. And if I do get a touch of colic . . . or have a nervous breakdown . . . do you know what'll bring it on? Worry! Yes, sir, worrying about how long it would take us to get the doctor if anything happens.

"Or suppose a pipe bursts in the bathroom? Or a burglar comes along? When something like that happens you don't write a letter. No, sir, you hop to a telephone!

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THE JOURNAL OF ENGINEERING EDUCATION

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THE COLLEGE STATION MEETING

By H. C. DILLINGHAM

Chairman, Local Committees, A. & M. College of Texas

In a few days the forty-sixth Annual Meeting of the Society will begin at the Agricultural and Mechanical College of Texas. For the first time the Annual Meeting has come to the Southwest, and the members of the Texas Section promise you a real welcome and a program of unusual interest. The members at College Station are particularly hopeful you will soon be their campus guests.

"The Cultural and Professional Phases of Engineering Education" is the theme of the meeting and will be the principal topic of the General Sessions. The contributions to this subject by Dean Earle, President of the Society, Dean Potter of Purdue, President Calhoun of Texas, President Walton of A. & M., Dean Kimball of Cornell, Dean Woolrich of Texas, Mr. Eshbach of the A. T. & T. Co., Mr. Thomas of Texas Power and Light Co., Dean Daggett of Rutgers, Dean Dodge of Oklahoma, Dean Leland of Minnesota, Dean Hammond of Penn. State, and others will be of instructive and inspirational value to all engineering teachers. President Compton of M. I. T. will deliver the principal address at the annual dinner. The seventeen Division Conference groups offer a wide variety of subjects in their programs.

We want you to become better acquainted. There will be plenty of time and places for "visiting." The Registration Desk and two large lounge rooms are in the same building. All meeting places and dormitories are nearby; the Dining Hall is only 800 feet away. We want you to attend the sessions and conferences and then devote the rest of your time to visiting, story-telling, or "gossiping"—if an engineering teacher may do such a thing.

A swimming pool, tennis courts, and softball diamonds are on the campus. A golf course is only four minutes away. The coast country will offer salt water fishing. You can get all the outdoor recreation you desire—no one would object to your playing a round of golf before breakfast.

We promise you a real Texas barbecue with trimmings—some of "extra curricula" trimmings may be red bugs—chiggers to some people. There is no charge for either activity.

The ladies will be treated to Mexican food, American bridge, colored education, Texas style, and if enough demand is evident,

they might even find Southern fried chicken and an old time square dance. We plan to put the children in the swimming pool regularly and join them at frequent intervals.

Highways in Texas are wide and long, but you can make miles in a day. No bottlenecks, no speed traps, no toll bridges, and not too much traffic make driving a pleasure. See West Texas, the Davis Mountains (peaks over 8000 ft.) or go to Mexico as far as Monterey, if not to Mexico City. We can give you the "dope" on how and what to do. If you have trouble finding College Station on your map, look for A. & M. College on the map we sent you.

You will probably not be in a hotel, but the dormitories will be clean and comfortable. Your food will be inexpensive but good. You may shed your coat—in fact we may require it. Bring your light clothes and some sport clothes—your white duck trousers will be fine for the barbecue or golf. Leave your formal clothes at home —and most of your dignity with them. Laundry is no worry—one-day service at a cost that will stagger you—it is so cheap.

Tell your railroad agent you want a ticket on the Mo-Pac or the S. P. Tell the bus agent you want a Greyhound ticket, or crank up your old car, grab a map at your local auto club, and travel. You may even use the far-famed and active thumb—it's legal in Texas. Anyway, we hope you come. We will enjoy your being here.

ADDITIONS TO PROGRAM

WEDNESDAY, JUNE 29, 1938

9:00 A.M. Cultural Phase of Engineering Education. R. A. Seaton, Dean, Division of Engineering, Kansas State College.

THURSDAY, JUNE 30, 1938

9:00 A.M. Professional Phase of Engineering Education. P. H. Daggett, Dean, College of Engineering, Rutgers University.

A Program for Unification and Correlation in Engineering Education. T. H. Morgan, Professor of Electrical Engineering, Worcester Polytechnic Institute.

WHAT TO SEE IN TEXAS

By JOSEPH W. RAMSAY

Secretary, Texas Section S. P. E. E.; Chairman, Department of Electrical Engineering, The University of Texas

Delegates to the 1938 Convention of the Society for the Promotion of Engineering Education at Texas A. and M. College will have a wonderful opportunity to visit many places that are famous in the history of the greatest State in the Union. Born amid pioneer surroundings and emerging from a struggle for freedom, unique in the annals of history, this State proudly boasts her own Declaration of Independence, her own private national history, her own public domain, and her gallery of famous Texans. Heroic deeds of Texas soldiers, Texas rangers, Texas cattlemen are not tradition, for these men, or their families, their children still live and walk among us. Texas is still young and still learning her own possibilities. Her children find inspiration to greater achievement on every hand.

Almost with her first efforts to organize her national government, the governing body took steps for the establishment of higher education in Texas. Out of those early efforts was born a movement resulting first in the establishment of Texas A. and M. and The University of Texas. Engineering education speedily found a place in the curricula of both of these schools. Since that day the State has added engineering schools at Lubbock, in the "Panhandle," *i.e.*, Texas Technological College, the State School of Mines, at El Paso, and the College of Arts and Industries, at Kingsville. Besides these senior colleges there are several junior colleges which give two years training in engineering. There are two non-state supported engineering colleges. At Dallas, the Southern Methodist University maintains a Coöperative Engineering School. Rice Institute, located at Houston, has rapidly forged to the front by the quality of its training in engineering.

The University of Texas and the Texas A. and M. College are located but a scant hundred miles apart. Believing that educators attending the Convention will want to visit the campus of one of the greatest universities in the South, the University Engineering Faculty is planning to entertain at the University as many

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CAMPUS OF THE UNIVERSITY OF TEXAS

Picturized by Elwood M. Payne, Austin, Texas

UNION BUILDING AND LIBRARY TOWER, THE UNIVERSITY OF TEXAS

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ENGINEERING BUILDING, THE UNIVERSITY OF TEXAS

of the delegates as will accept their hospitality. They extend a hearty invitation to all to come to Austin, Friday morning, July 1, where they will be conducted on a tour of inspection through the buildings, laboratories, the new museum, and our magnificent library. Provisions will be made for the guests to obtain luncheon at the famous University cafeteria, where an excellent meal may be obtained at from twenty-five to fifty cents.

SKETCH SHOWING LOCATION OF ENGINEERING COLLEGES IN TEXAS, AND PROXIMITY TO U. S. HIGHWAYS

After inspecting the campus, the delegates will be taken on a tour to many of the historical sites located in the city.

The University of Texas, established by the Legislature in 1881 and located at Austin by popular election, was formally opened September 15, 1883. The total enrollment has grown from 211 in 1883 to over 10,000 in 1937–38, giving it more than the combined enrollment of any other two universities in the South. The University of Texas has almost completed thirteen new buildings at a

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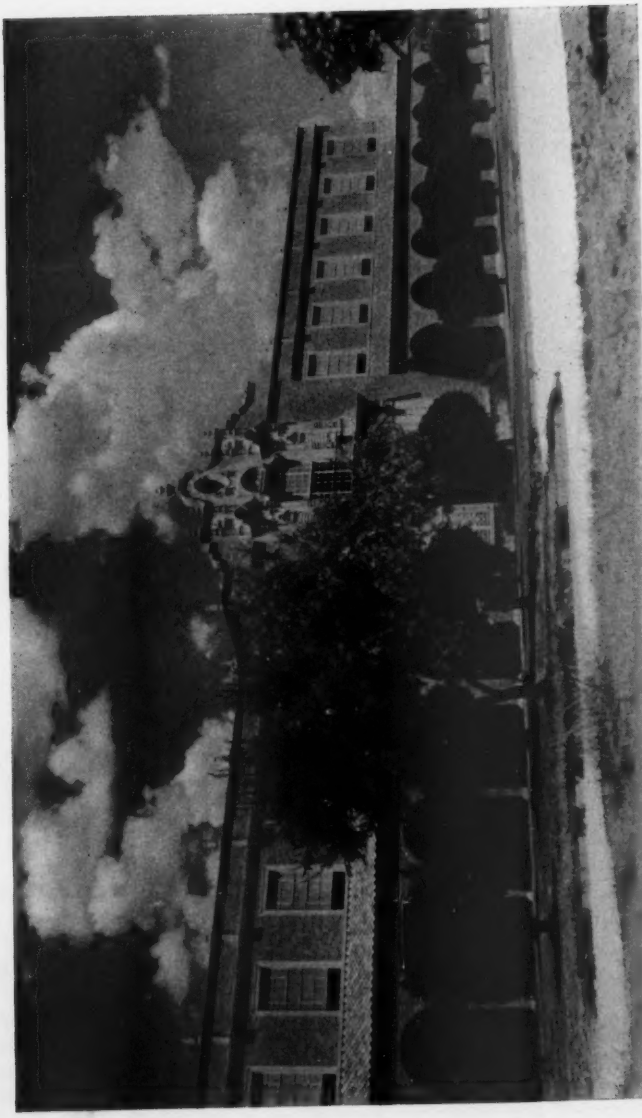

TEXTILE ENGINEERING BUILDING, TEXAS TECHNOLOGICAL COLLEGE

TEXTILE ENGINEERING BUILDING. TEXAS TECHNOLOGICAL COLLEGE

Photo by Reeves, Lubbock, Texas

MAIN ENGINEERING BUILDING, TEXAS TECHNOLOGICAL COLLEGE

cost of over ten million dollars. There are thirty-four buildings comprising the University physical plant at the present, and this number will be increased when the building program now under way is completed. The most impressive of these buildings is the new Administration-Library unit. The tower of this building is 308 feet high and will hold approximately three million books.

The University of Texas is located in Austin, the capital of Texas. Austin has a population of 60,000, one-third of which are attending some of its many educational institutions. Austin's many historic buildings include the Capitol, constructed of native red granite and dedicated in 1888; the home of O. Henry, master short-story writer; the French Embassy building; the Governor's Mansion, typifying Colonial architecture, which was constructed in 1855; St. David's Episcopal church, established in 1847; the Elizabet Ney Studio; and the home of Amelia Barr, well-known authoress. The recreational advantages include the bathing resort of Barton Springs, Zilker Park, and other delightful spots which have all the natural beauties and facilities for outdoor enjoyment.

The medical branch of the University is at Galveston.

San Antonio, unique city of 300,000, is situated eighty miles southwest of Austin. Here is the Alamo, cradle of Texas liberty, a fortress which in 1836 fell before the onslaughts of an overwhelming Mexican army, but not until the last one of its defenders had given up his life. Here, too, still standing, are several of the old Spanish missions, dating back almost to the days of Cortez.

Nearby is Randolph Field, proudly called the "Westpoint of the air," where the United States Army trains the cadets who will become the Nation's flying soldiers. Fort Sam Houston, Kelly Field, and Brooks Field, all of which played prominent parts in training the men of the A. E. F. in the stirring days of 1917–18, are still active parts of the Nation's military establishment.

San Antonio will be found to present an intriguing mingling of Old Mexico and of modern America. Those who have never seen this entrancing city should not fail to avail themselves of a visit there.

Houston, with 350,000 inhabitants, lies approximately two hundred miles east of San Antonio. It is surrounded by oil fields, cattle, fruit, and farming country. It is served by many railways, excellent highways, and a deep water ship channel to which come ships of all nations.

The Rio Grande Valley, "magic valley" of South Texas, offers all the charms of a California or a Florida, and is easily reached via excellent highways.

Travelers across West Texas will find the McDonald Astro-

nomical Observatory in the Davis Mountains south of United States Interstate Highway No. 290.

One of the geological wonders of the world is the Carlsbad Caverns just over the State line in Southeastern New Mexico. This may be reached by an easy drive from Lubbock or from El Paso.

There is space here for only a very brief and inadequate recital of the greatness of this State, but we in Austin hope that those of you who see this article may be so intrigued that you will want to see as much of it as possible while here, and that you will honor our group at The University of Texas by accepting our hospitality for a while.

REPORT: PROGRESS IN ENGINEERING EDUCATION

1936–37

Society for the Promotion of Engineering Education

Note: This third annual Progress Report continues the record of significant events, developments and trends in engineering education. Officers and Chairmen of the S. P. E. E. were requested to report items regarded as significant and their replies form the basis of what follows. The report is selective and not exhaustive. Prior reports appeared in the JOURNAL OF ENGINEERING EDUCATION, February 1936 and April 1937.

FORTY-FIFTH ANNUAL MEETING

"Something has happened to our annual conventions," said the Progress Report a year ago; it continued—"The average attendance of the last three conventions approximated 1,000, about double the prior five year average." The Massachusetts Institute of Technology-Harvard University convention of 1937 numbered well over 1,500. The Society membership then was only 2,582. There were activities a-plenty—as portended by a 36-page program (May '37, p. 627) *. Interest as well as numbers increased. Reasons assigned for this vitality are, the establishment of sectional and divisional programs of such character that the teacher as distinguished from the administrator gets assistance on his everyday problems. "It is one thing to hear a president or a dean talk about something that one can do nothing about (which will be printed in the JOURNAL) and quite another to hear a paper on the teaching or content of a course that one is actually teaching. It is the bringing of the programs down to actual problems which has stimulated such great interest."

Even the general addresses dealt with actual practical problems. President Hammond's address on The Engineering Teacher (Sept. '37), the general topic of the meeting, is interesting and stimulating. Many problems would disappear "If as much care were devoted to the choice of a beginning instructor as to the head of a department." One who delights in his actual practical teaching problems may get himself into perspective by the illuminating addresses by Compton and Feiker and Dodds and Whitehead and Potter (Sept. and Oct. '37).

Conferences at the Meeting.—The score of conferences which put

* References are to JOURNAL OF ENGINEERING EDUCATION.

life into the annual convention reveal to the observer who attends them a spirit of earnest interest, particularly by the younger group, which formal programs and reports do not show (Nov. '37, p. 148). In conferences, "The trend toward scientific and technological is pointed out by President Hammond and accepted, provided the educational aspects hold a prominent place; also individual freedom of groups is commended, provided there is reasonable coördination. New men, young men, are alert and assuming leadership." Following these sentences from last year's report, two present trends are significant. First as to coördination, the Electrical Engineering report says: "The Society has been analyzing itself into divisions and subdivisions; now these components are realizing that they have important interests that are common. Of our five conferences, four were joint conferences" (Nov. '37, p. 177).

Second is the shift of the conferences from the oft-times impromptu committees to formally recognized groups—virtually independent self-activating societies—they are termed Divisions. They are duly organized and officered and have continuing objectives and progressive programs. There are now nine Divisions —Chemical, Civil, Coöperative Education, Electrical, Drawing, Mathematics, Mechanical, Mechanics and Mineral Technology (Nov. '37, p. 168). Other groups are active under committee organization. The English group has had for years a persistent vitality which proves contagious. In the S. P. E. E. there is developing the method by which engineering societies grow—whenever a little group has a common interest and adequate urge, it goes off by itself and begins a free and vigorous life. Hence have come our several major societies and a legion of special ones. It facilitates development—also diversity. S. P. E. E. has successfully coördinated voluntary effort in the past; fortunate if in the future it can rear a happy family.

Comment on Conferences

First Surveying Teachers' Conference, July 25 to August 5, 1937, at Camp Marston (of Iowa State College) located in Minnesota, brought together 31 teachers from 26 institutions, also 40 camp followers. Topics: Minimum requirements for surveying courses; elementary surveying; advanced surveying; photogrammetry; "curves and earthwork." Inaccessibility and life in "one large family" conduced to consideration of "Improvement of Surveying Instruction"; the Conference "will influence surveying practice and its teaching in engineering colleges for many years" (Nov. '37, 211).

Engineering Economy Committee: (1) Promoted a session on the Economics of Engineering (joint project S. P. E. E. and Stevens

Institute) at Stevens Camp, Johnsonburg, N. J., June 18–26, 1937. Attendance of 80 was greater than the preceding year and was about equally divided between teaching and industry. Topics: Teaching methods and course content in economic theory, engineering economy, accounting and industrial management and their interrelations; industrial economics. The informal camp life was conducive to out-of-hour discussions. The Stevens facilities were highly appreciated. (2) The conference at the convention brought together six S. P. E. E. groups and brought out similar problems in different fields. (3) An "Engineering Economy Page" in the monthly JOURNAL now rivals the English Notes and the T-Square Page. The new Page sponsors a quest to find a definition for "Engineering Economy" (Nov. '37, 234).

The New Mechanical Engineering Division (including Machine Design).—"Several independent and conflicting groups have been brought together making possible real and continuous progress in mechanical engineering education." ". . . the effect of the increasing emphasis of mechanical engineering curricula on science and scientific processes with a general lifting of their emphasis from the purely empirical." "Among the conferences the one on Mechanical Engineering was, I think, outstanding." These come from competent commentators (Nov. '37, p. 194).

In Chemical Engineering the quantitative approach to its problems now permeates its curriculum. Descriptive courses in industrial chemistry have been eliminated or advanced to the junior or sophomore year. Organic chemistry and physical chemistry have been advanced a year earlier. Unit operation courses accompanied by laboratory quantitative measurements are a major interest in the last two years. There is new interest in a chemical engineering approach to organic processes and problems involving reaction kinetics and catalysis. Engineering economics is receiving increasing attention (Nov. '37, 69).

The Committee on English announces a grant of $2,500 from the Carnegie Foundation to the Society to be used in financing a study of instruction in English in engineering colleges. The objectives and methods of the proposed study were given preliminary consideration at the 1937 conference on English (Sept. '37, pp. 22, 33).

ENGINEERS COUNCIL FOR PROFESSIONAL DEVELOPMENT

In the annual report the Chairman, C. F. Scott, reiterates the task of E. C. P. D., now concerned with the progress of young engineers, is to meet "The challenge to the Engineers of Today to assure better Engineers Tomorrow." The method is "to think, to plan, to propose, to act through the coöperation of organized

engineering societies." The non-technical phase of engineering is emphasized; also the opportunity of the publications of the societies to further cultivate this broader element, particularly for the younger engineer.

After graduation comes the "School of Experience. It should be a laboratory for the application of principles to problems and the solving of problems by applying principles—knowledge and experience should become integrated so that they interact and produce something far beyond the arithmetical sum of textbook information and the doing of rountine tasks. What should result is that facility and judgment which characterize the competent engineer. But some emerge with diploma certifying to things forgotten and unused, and a list of jobs."

The Committee on Student Selection, R. L. Sackett Chairman, considers the interests at stake in the selection of 25,000 freshmen from hundreds of thousands of high school graduates as concerns the individual and society, the school and the profession. Continuation of the coöperation between local engineering groups and high schools is reported. At a conference on pre-college guidance at the S. P. E. E. convention, the novel selection methods at Worcester, Columbia and Stevens were presented and discussed (Nov. '37, p. 204).

The Committee on Engineering Schools, Karl T. Compton, Chairman, reported on October 1, 1937, that since the accrediting program was inaugurated in 1935, 134 schools have submitted 645 curricula; 129 institutions have been visited and recommendations prepared on 626 curricula. Twenty-one degree-granting engineering colleges have not yet responded to the invitation. Results: To accredit 374; to accredit provisionally for a limited period 71; to defer action 8; not to accredit 173; total 626. A complete list of the accredited curricula is in the Supplement to the JOURNAL OF ENGINEERING EDUCATION, October 1937.

Supplementing accrediting is possible aid to institutions offering curricula for accrediting. The visiting committees have been asked to give suggestions and advice and have endeavored to comply. Through the discussions of the committees, attention has been given to the directions along which substantial improvements might be made.

Activities in Prospect are: Continuation of accrediting program, investigation of graduate study, study of admission with advanced standing, advisory service to institutions, survey of engineering education. The latter contemplates an analysis and publication of information recently acquired on the status of engineering education during accrediting. For this project the Carnegie Foundation has provided $10,000 (Mar. '38, p. 471).

The Committee on Professional Training, O. W. Eshbach, Chairman, is urging the local groups—particularly the sections of the national societies to concern themselves with the recent graduates in their localities.

It has completed and issued "Selected Bibliography of Engineering Subjects" in five sections, prepared by the Chairman with the coöperation of over 100 practicing engineers and teachers. It is commended by Engineering Societies Librarian (Sept. '37, p. 8). (These as well as the Annual Report are available at nominal charge from E. C. P. D., 29 West 39th St., New York.)

The Committee on Professional Recognition, C. N. Lauer, Chairman, encounters a perplexing problem—but a fundamental one—in attempting to correlate the present varied procedures in recognition. Just who is an engineer is a question which is vital to the segregation of the engineering profession, The Committee is studying the basis of older "professions" in other fields.

President Wickenden and the chairman attended a conference of lawyers, doctors, dentists, and engineers on education for the professions. Others are not at all satisfied with the present status of education and of admission to their professions. The "professions" involve many problems calling for the best thought in their development.

Society Items

The Depression.—The Society has passed through the period of depression with its financial status better than ever before and with its morale and activities at a high level, due not only to sound management, but to the devotion of its membership at large.

Section activities of the Society are stimulating interest. More papers, or as many, are published from sections as from divisions. The division meetings are yearly while many sections meet twice a year. Sectional papers also deal primarily with the ideas of the younger men and every effort is made to publish as many as possible.

Local sections may build their programs as a development of the theme of the national convention.

Engineering Societies.—There is a notable growth in the cooperation of the educational activities of the professional engineering societies with that of the S. P. E. E. There are now several committees that automatically place the chairman of the corresponding S. P. E. E. group either as chairman or member of the educational committee of the society.

Graduate Study.—The comprehensive report on graduate study under direction of a committee headed by H. P. Hammond was published as an official document by the Office of Education, Wash-

ington. (Obtainable from the Superintendent of Documents, Washington, D. C., price 15c.)

Meeting Places for conventions have in the past been the verdicts on oratorical excellence in presentation speeches—sometimes as midnight approached. A committee (presumably by its chairman) has evolved a formula for indicating which way to go for our next meeting to insure geographical and institutional equity. A step towards stability (Dec. '37, p. 255).

The Council at the Convention.—Asked the Executive Committee to propose policy as to publications by divisions and other groups; also policy for committees and divisions; ruled that summer sessions or conferences (except at annual meetings) require authorization; ruled that Editor is not expected to abstract papers but may request authors to brevify; publications carrying the Society name must be O.K.'d; made recommendations reinstitutional membership relating particularly to accredited institutions (Sept. '27, pp. 22–26).

The Annual Meeting of the Society.—Received recommendations and changed By-Laws as to institutional membership (Sept. '37, p. 29); received for action at 1938 meeting in College Station, Texas, changes in Constitution as to institutional membership; received and filed resolution from Committee on Professional Status and Employment on recruiting of students by industries (Sept. '37, p. 31).

Publications.—The Secretary's Report presented our acute publication problem and offers suggestions (Sept. '37, p. 34).

How Big Are We?—The year book (Feb. '38) lists 6 officers; 21 elective members of Council and 23 ex-officio; 9 divisions; 18 sections; 14 branches; 23 committees; 12 other organizations on which there are S. P. E. E. representatives; 108 active institutional members and 28 associate, total 136; 2,766 individual members. (There were, last June, 120 institutional and 2,582 individual members; gain, 16 and 184.)

The Lamme Medal.—The 10th award by this Society was to F. E. Turneaure, Past President of the Society and long-time Dean at the University of Wisconsin (Sept. '37, p. 1). In the presentation the remarks of E. B. Roberts and President Hammond referred to early personal relations with Dean Turneaure and his textbooks (Sept. '37, p. 29).

Educational Comment

One Pattern for Tremendous Diversity.—In his presidential address, President Hammond states a serious situation. Note the following phrases: We have virtually but one pattern in collegiate education: The American collegiate system. The engineering college is almost the sole agency for preparation for a tremendous

diversity of industrial pursuits. In the one institution the attempt is made to prepare men of widely varying abilities for such a great variety of services both as to types of work and levels of responsibility that the process inevitably becomes one of compromise (Sept. '37, pp. 9, 10).

Progress in Engineering Education is determined by the equality of graduates. The following items bear upon improvement:

1. Subsidence of engineering activities under WPA and other agencies. Socialization of engineering under a planned economy seemed to be growing. Students began to think in terms of government employment primarily. Readiness to accept without question construction policies of political origin, so long as it afforded jobs, had made headway. Economic and social propriety of engineering works threatened to pass from the engineering profession to pork-barrel agencies. Building regardless of economic justification has, fortunately for engineering education, come to a pause.

2. Restoration of apprenticeship courses for our graduates entering industry is a forward step.

3. In fluid mechanics the generalization of disconnected observation is progress toward fundamental as contrasted to empirical science and will affect teaching of the future.

4. "Sophomore Comprehensive Examinations" (Jan. '38, p. 378) combined with records of the first two years give an amazingly high prediction reliability as to graduation.

5. Growing influence in the utility of E. C. P. D. accrediting may be mentioned, supplementing the report of last year.

6. Clarification of the issues in the unicnization of technical employees: namely, that unionization under any general labor organization surrenders any claim to profession that engineering has ever had; that those who seek unionization are largely in the lower range of competency and are often the social mal-contents.

Advance in engineering education is not like a company advancing together on a parade ground; there are individual advances in different localities, a bit here and a bit there, and presently the line has advanced.

Accrediting by E. C. P. D.—The examination of the schools caused careful consideration of curriculums, equipment and quality of staff and the result is bound to be very helpful.

The Shorter Working Week gives more opportunity to young engineers for home study and emphasizes the E. C. P. D. program for younger engineers. They are at a period in their lives when they are interested in their relations to society and to the community in which they live.

Industrial Engineering.—Interest in instruction in manage-

ment increases notably among teachers in the older technical departments. This may be due partly to interest of employers in having graduates who have some background in management.

"Graduate Study in Engineering Schools" (Jan. '37, p. 435) is a courageous article which has a very large and general significance and the viewpoints are equally applicable to undergraduate instruction. Research has overreached itself.

Character Factors in engineering success were emphasized at the Kansas-Nebraska meeting. They should be developed as a part of the instruction in technological subjects, and not as a thing apart from professional training.

National and International events are forcing engineering educators to concentrate their thought upon the problem of introducing a sufficient and a properly balanced treatment of these topics in engineering curricula. This may be recognized as a definite trend of the present time which may be reflected by curriculum revisions in the near future.

Potpouri

Revolt of the Secondary School against continuing to teach all students as though they were being prepared for college is an outstanding event of the past year.

Institutes or short courses for practicing engineers and surveyors have more than doubled in Florida and North Carolina during the year.

American Engineering Council is composed of seven national societies (S. P. E. E. is one), fifteen state societies and thirty local societies. "Members of S. P. E. E. have an important part in this agency for advancing public welfare," says Dean Potter, for the past two years its president.

Engineering Enrollment.—Last year's report gave the approximate freshmen as follows: 1930, 25,000; 1932, 17,000; 1935, 20,000; 1936, 23,000. Now may be added 1937 (Dec. '37, p. 369) 27,700. The latter figure represents 131 institutions, which is 10 per cent more than reported a year earlier.

The Distribution of Freshmen among the four principal groups as given last year was approximately, mechanical one-third, chemical and electrical one-fourth each, civil one-sixth. The same ratios hold closely for the freshmen, sophomores and juniors of 1937–38. In the senior class there are a few less mechanicals and a few more civils.

The sophomores in these four curricula exceed the corresponding freshmen of the preceding year by 40 per cent, or 4,000 students; presumably recruits have come from the 8,000 "unclassified" freshmen. The four curricular groups constitute a little less

than half of the total freshmen and nearly four-fifths of the total seniors.

Committee, 1936–37 Report,
F. C. BOLTON,
H. V. CARPENTER,
S. B. EARLE,
P. W. OTT,
CHAS. F. SCOTT, *Chairman*

NOTE

Members who have read the foregoing report are asked to send their comment to Secretary Bishop—Does it add a worthwhile picture to "the panorama of the unfolding years" for the future reader? Does it give a convenient summary to the present reader? What items would you omit? What would you condense? What would you add?

WHAT INDUSTRY EXPECTS OF THE ENGINEERING GRADUATE*

By C. T. REID

Asst. Chief Draftsman, Douglas Aircraft Co., Inc., Santa Monica, Calif.

The first thought that comes to mind is that what industry expects depends to a great extent upon the industry. However, this comment applies to specialized training and if we limit our discussion to general characteristics of engineers and engineering, we may hold a stage of more universal interest. Nevertheless, aircraft design and manufacture, the line with which the writer is connected, is an exacting problem ideally suited for engineering approach and its contributions to the study should therefore, be significant.

We will begin with a number of random personal observations and then try to catch the view-point of some engineers in aeronautics who responded to a recent survey solicitation.

Industry expects the young graduate to come in with a lot of fundamental technical knowledge, but without an over developed sense of self importance. A fine education flaunted by a man offering his services for employment is like a box of shiny new tools displayed by an applicant mechanic—highly desirable, if they can be put to use. Both types of applicant must demonstrate their ability to use the equipment they have.

The young graduate must appreciate the value of a practical knowledge of the business as possessed by the "old timers" even though they be less well educated technically, and must be willing to get his hands dirty learning the practical angles for himself. He must not resent having to take an ordinary job (at ordinary pay) as a beginning assignment to prove himself deserving of higher responsibility.

Before he can enter well into the production routine he must know about the tools, machinery, materials and language of the industry. Book theory of design cannot alone suffice.

He must go through a reasonable amount of humdrum routine production work for thorough seasoning before casting a hopeful eye upon any executive or research assignment.

Coming in inexperienced, it is assumed that he will have only

* Presented at the Sixth Annual Meeting of the Pacific Southwest Section, S. P. E. E., Los Angeles, December 29, 1937.

a fair appreciation of good and bad shop practice, but with it he is expected to have an eagerness to make the most of every opportunity to acquire detailed knowledge of this subject, learning on the job. A total absence of the notion "Now I am educated" is a virtue.

The young engineer should have ability to express himself well in writing—not only with good grammatical construction, but also in a neat hand and with scrupulously correct spelling. If spelling is a weak point, the student should invariably be required to do special work to bring it up to standard before being considered for a diploma. A beautifully printed but sadly misspelled word staring one in the face from the middle of a drawing or engineering report is an abominable thing. You may be surprised to hear that frequently a college graduate returns our application form to us so marred by misspelled words throughout that it is immediately relegated to a very low classification of eligibility, if not consigned to the waste paper basket.

Our young beginner should be able to express himself effectively in speech as well as in writing. He needs this faculty not only in order to talk to an assembled conference group without suffering from a disastrous amount of stage fright, but also to enable him to explain a proposition straight-forwardly in simple clear language to a fellow workman.

The young engineer needs a common senses grasp of the economics of his industry. This is particularly true in a small informal engineering organization. Without it he may, when responsibility permits, overspend for equipment, "research to death" his engineering staff or overproduce ahead of sales.

He must have ability to get along with people—to see both sides of a question under dispute. A good cultural development is a reasonable thing to expect of any college graduate, but unfortunately the expectation is not always realized.

Now let us see just how engineering graduates in a representative lot employed in the aircraft industry express themselves about what they have found that industry expects of them. The writer recently asked all the graduate engineers in key positions on the Douglass staff plus those who had gone through the shop training course, to enumerate, from the view-point of the title of this paper, the subjects that they have often wished they might have studied in college or studied more exhaustively. The seventy-seven per cent who responded were:

3 Bachelors of Arts
2 Mechanical Eng. Bachelors of Science
5 Aeronautical Eng. Bachelors of Science
1 Civil Engineer Master of Science
5 Aeronautical Engineer Masters of Science
1 Ph.D. in Physics
1 Ph.D. in Aeronautics
and 1 Dr. Ing. in Aeronautics

The schools they came from are:

Stanford University
California Institute of Technology
Massachusetts Institute of Technology
University of Washington
University of California
University of Minnesota
University of Akron
Purdue University
Baldwin Wallace
and Aachen

They contributed a considerable variety of subjects and an effort has been made to classify them as follows:

	% of the Total of Items Turned in
Mechanics	21%
Business	18
Physics (other than mechanics)	12
English	11
Sciences (not duplicating above)	12
Foreign Languages	8
Psychology	7
Drafting and Design	6
Mathematics	5
Purely hobby items	2
Total	100

These are the things the engineers wish they had studied because of what they find industry expects of them. It should be kept in mind that their industry is airplane design and manufacturing. Each group will be discussed briefly by way of amplification.

In the "Mechanics" group the largest number of items pertain to materials and their stress analysis with many notations to the effect that there should be more detailed study including more

treatment of practical problems. Dynamics including aerodynamics and fluid mechanics in general brought a secondary quantity of items under the same heading.

"Business" is the term applied to that group of items covering business law, industrial management, etc. Most of the items submitted referred to organization and management.

The "Physics" group with "Mechanics" excluded covered electricity, optics and acoustics in about equal interest manifested, with a few other general notes.

Under "English" appeared variously worded suggestions that more attention be given to teaching the student to express himself effectively in conversation and public address. Some mention was also made, however, of better training in composition of technical papers.

Under "Sciences" (other than those included in the preceding) chemistry was mentioned most prominently with particular emphasis upon metallurgy. The need of a better understanding of corrosion problems and metal processing was strongly brought out.

"Foreign Languages" came in for quite a lot of side comment some of which was contradictory, but in general it summarized very well to recommend two things; first that the languages which an engineering student should always study are those of the other countries who produce the prominent engineering achievements, namely French and German (with some mention of Italian); second, that these should be so studied as to develop the technical vocabularies rather than treat the subjects in literary fashion. An engineer wants to use his knowledge of foreign languages to read test reports, technical handbooks and trade journals. He cares nothing for the poetry, drama and period fiction of another tongue unless it happens to be a hobby interest. Why then must he study in the same classes with liberal arts students and finish up totally devoid of the technical vocabulary that is his prime need?

A group for "Psychology" had to be provided to classify the subjects dealing with personal relations and the several cases where just plain psychology was mentioned as an item.

Under "Drafting and Design" were classified several items dealing with particular specialties such as instrument design, and design of industrial automatic control equipment. Two graduate engineers did, however, confess that they had felt a need for more training in ordinary engineering drawing. The employers are likely to vote much more strongly on this point. We seldom find a young graduate who is really well grounded in machine design drafting practice.

Under "Mathematics" we have only items expressing in various ways a wish for more training in practical applications of mathe-

matics with a very minimum of routine solving of problems by formula.

The essence of all the comments collected in our survey was a cry for more practical training. Too many courses are reported to have been given by instructors who were expert in the scientific phases of their subjects but had little practical knowledge of their field of application. It was suggested that studies habitually be presented in such a way as to show or at least explain the practical applications of theoretical points.

In addition to the items classified in the foregoing, each engineer granted our request that he also mention the college studies that he considered had been of little use to him. As might be expected, this presented the opposite side of some of the same arguments because what one man lacks and wishes for, another has and despises. This came out strongly in regard to foreign language study, and also figured in those engineering specialties which lie slightly outside the aeronautical field. The natural conclusion is that for research and highly theoretical engineering a thorough facility at perusal of French and German reference works is desirable, but for the general run of production design, drafting, and manufacture it is of considerably less value. Similarly, courses in electrical, steam and gas engineering, and even surveying, may be of value on certain special assignments in aircraft, but these studies will in the great majority of cases be found rather unserviceable.

All this points to the old familiar principle that only those few students who have a well developed notion of what they want to train for, have any chance of getting really fine training. Here we face a real difficulty, because this day of specialization demands such specific training. In general, mechanical engineering training makes the best preparation for aeronautical engineering work, but if the student is sure of his aeronautical preference, he should eliminate the steam engineering, heating and ventilating, etc. from the regular mechanical engineering course and substitute subjects of more direct application to aeronautics. However, suppose he does settle upon aeronautical engineering, he still may use up much valuable time on things that ought to have been touched but lightly unless he can further break down his choice of occupation. Only a very small percentage of aeronautical designers need to be proficient at gas engine design—or the design of propellers—or instruments. Relatively few need a thorough knowledge of aerodynamics. Design of light weight structures and mechanisms is the principal occupation of the vast majority of aeronautical engineers. However, those who are to spend full time on engines, propellers or other specialities need not make the exhaustive study of stress

analysis of stiffened thin metal sheets that the regular run of men need. This dilemma of specialization and sub-specialization in aeronautical engineering undoubtedly has its counterpart in each other industry.

Probably too many young men rush into college (or are rushed in) before they have any idea of what industry is all about. Some way, somehow they need to get an inspiration as to life work before beginning to use up precious college hours. This is a definite need, however hopeless to expect under the present regime.

Another sad thing is that many who manage to get through a four year course are not, and would never be, suited for engineering work at all. One authority on this subject recently said that in his opinion the colleges are just spoiling a lot of good plumbers! It very possibly is true that a high school education plus trade school specialization would be more appropriate training for many who misguidedly struggle through four years of engineering college study.

The quality of any raw material is likely to be far more important than its refining process. A college or university is similar to a refinery. The ability and capacity of its graduates is directly proportional to the ability and capacity of the men admitted as freshmen. Grade of quality is determined by thinking or reasoning power, potential capacity, personality, character annd health. Forming these original qualities in men is a function of nature by way of heritage, plus boyhood environment and training. Thus, probably the most important formative stage is beyond the direct control of colleges and universities. In the next stage, however, they can influence the type of graduates by lowering the financial barriers and raising the required standards of intelligence. Much progress is being made in this regard at the present time, but little has been done to encourage the desirable graduate to give thought to future generations. Instead of encouraging people of intellectual attainments to raise families we are, generally speaking, content to see all the large families raised by people of inferior intellectual qualifications and low standards of living, who are perfectly satisfied to eke out an existence on small incomes or public relief. From these families eventually will come the majority of the college enrollment. This is something to think about! So much for the raw material.

Now for a slant on "the refinery." The ultimate goal of education is to make a man more fit for future living. The largest component of living is the value of a man to his fellow men. For a certain portion of this value, he is in turn rewarded by a pay check which may be exchanged for the fruits of other men's labor. Today these fruits, which may be necessities or luxuries, are not grown

or manufactured by one man but by the combined efforts of many men and women. The efficiency with which the items are produced depends upon the cooperation of these men and women. Therefore, it is obvious that the success or failure of a business today, or of a country for that matter, depends largely upon the cooperation of its personnel. Keen competition is the referee.

Colleges have taken steps to teach cooperation by encouraging cooperative sports and activities. However, some lose sight of this objective in class training and class room "atmosphere." They fail to emphasize the importance of one's ability to get along with fellow students. This ability is increased simply by being courteous and having consideration for others. Generally speaking, men from the older institutions of learning seem to have more spirit of working together than those from the younger ones. Their cultural development is more pronounced. Industry's interest in the cultural development level on which a prospective employee stands is focused upon the culture that makes him work well with his fellow men. Other than in this respect industry begrudges time taken for purely cultural studies that might have been devoted to the practical things used to win bread and butter. In industry a highly cooperative person is a highly desirable employee.

Foremost in importance in engineering is accuracy. We find many technical graduates lacking in this trait. Often their inaccuracy is due to carelessness or lack of training. Closely related to accuracy is neatness of work, and neatness of work is often indicated by neatness of appearance. The personal appearance of a student on the campus is not without value as an index of the neatness of his work later in industry.

Most colleges practically neglect discipline. Some students enroll in an R. O. T. C. unit and receive disciplinary training there. It oftens happens, however, that the men who need such training the most neglect to avail themselves of the opportunity. Discipline is necessary for efficiency in any large group of people working together. Men must abide by company rules. They are formulated for the good of all concerned. A man must learn to take orders before he can give them. If discipline is learned, in at least a modified form, while in college, it may lessen the shock later. We have known several cases of very promising young engineers who lost opportunity after opportunity for advancement because they just could not work with other people decently. Industry can spare little or no time to run a character building school. Most such unfortunates quit their jobs in disgust, feeling that they have been dealt with very unfairly.

In some schools students are always shown a method and then given problems to be worked out by utilizing that method. This

is all right as far as it goes, but it does not supply the whole need. In the business world there arise many problems with no previously devised method of solution. When confronted with such a problem the young graduate often finds himself lost because he has never been trained to use his initiative. Circumstances often require that a new young employee perform duties without being told every step. Furthermore his ability to make suggestions as well as follow suggestions has an important bearing on his progress.

A man's ability to assume responsibilities is directly proportional to his dependability. Teaching dependability would be a difficult subject. However, a start in the right direction can be made if every student is required to keep his word sacredly even in trivial matters.

Regarding individual production in industry, work should be turned out within reasonable time limits. Too much meticulous effort is often just as bad as not enough. In this respect a student should be taught to use common sense. As a matter of fact a good course in the use of common sense would not hurt anyone. Returning to the point, an example of time wasted is making broad assumptions for the basis of a problem solution and then carrying the computation results to four decimal places.

Cooperation between educational institutions and industry will evolve more efficient educational training, thus increasing the fitness of college graduates for richer, fuller and more useful lives.

Discussion

By BOYNTON M. GREEN

Stanford University

Mr. Reid's paper seems to me an unusually clear-cut and comprehensive survey of the problems arising in the production of a desirable graduate in engineering. I wish to congratulate him on the excellence of his discussion. I have read many such statements from employers and have listened to discussions on the same subject. They usually boil down to a demand that we improve on the thoroughness with which we teach the fundamentals and at the same time increase the number of specialized courses. There is rarely any consideration of limitations as to time or of the many other factors which enter into the problem. Mr. Reid very evidently appreciates the definite time limitations imposed by the traditional four-year curriculum and he also appreciates that the mere transmission of information is only one of the many factors entering into the training of an engineering student.

It is very evidently the function of an engineering faculty to collect, study, and weigh, all such communications from industry and attempt to work out, within the established time limits, a curriculum which seems to meet best not only the demands of employers but also the needs of the student himself as a member of society. Therefore, I would now like to discuss what is being done and what further can be done to meet some of these requirements.

The problem of better training in English is a difficult one to solve. Teachers are fully alive to the problem and the S. P. E. E. is at present making an investigation of this subject under a grant from the Carnegie Foundation. The college is expected to make up for all the deficiencies in what little training the student now receives at home and in high school. It would seem to me that employers, as organizations and as individual tax-payers, could well exert pressure on the boards of education and on the administrators of the secondary schools to improve the quality of instruction in English composition, vocabulary, and spelling, now given in our schools. An article in the October Atlantic calls attention to the very poor English used by many of our popular writers. With such examples before them is it any wonder that engineering students do not take very seriously college training in English? We must show them, at every opportunity, that accurate and fluent English is essential to accurate thought and transmission of thought. This is something in which every teacher of engineering can assist, not only by example in their own use of English but by constant correction and advice. The requirement of written analyses of problems in many engineering subjects would give excellent training in the accurate use of words as well as training in clarity of thought.

In regard to engineering economics, more and more colleges are offering courses under this head. While general principles can, and should, be taught, the student has too little contact with industry to appreciate much detail.

I was much interested in the short discussion of drafting and design, and the hint that employers might consider many graduates quite deficient. I was surprised that a professional designer would be so mild in his comment. Drafting courses operate under the following handicaps: first, in most schools time has been taken from these courses to give to theoretical subjects. At Stanford, where conditions are about average, the total time in six years devoted to drafting practice is about 380 hours; equivalent to nine or ten weeks of commercial time. How proficient would an apprentice draftsman be at the end of this time? Second, quality and standards in commercial drafting rooms vary widely throughout the country so teachers have no definite goal at which to aim. Third,

it is a common saying among students and I have heard it stated among teachers that if a man is a good draftsman he will be put on design to stay. Regardless of whether this is actually true, it has a very definite effect on the student. Under present conditions, perhaps the most that can be done in college is to impart rudimentary training in line work and lettering and inculcate the idea that an engineering drawing is a somewhat conventionalized description of some structure; a description which must be complete without redundancy, truthful, and accurate. We must probably leave to industry the final training in facility of execution and the use of many specialized conventions.

Mr. Reid raises an important point when he emphasizes the necessity of a young engineer occupying minor positions long enough to become familiar with the practice of engineering and to prove his worth. The older engineer can see the reasons for such a novitiate but to the student, with his very limited knowledge of practice, such reasons are much less obvious and he is further influenced by the often repeated statement that certain of his courses are given in preparation for the higher positions. Teachers should seize every opportunity for emphasizing this initial phase of the graduate's career. On the other hand, I believe industry is often too severe in its requirements for "journeyman" training. The techniques so acquired should be of secondary importance; a future design engineer should not be required to become expert in the production of inked tracings—this can be done better and cheaper by a qualified high-school graduate; nor should a young railroad engineer have to become proficient in tamping ties. However, to prepare for these "proving-ground" jobs, there should be a continued demand for clarity of thought and statement and reliability in computations. Teachers too often excuse inaccurate statements and incorrect arithmetic with the remark "He *must* know better than that." Hand-in-hand with this training goes the training in common sense which can be accomplished by requiring that the student forecast his results whenever possible.

Mr. Reid stresses the desirability of courtesy and tact. A young person is often discourteous only because he has never been asked to give the subject a thought. He is often tactless with his instructor to ensure that he cannot be accused of "apple polishing." I have frequently found that improvement is marked when I submit the engineering view that courtesy and tact are the lubricants which must be applied to make our social machinery run with a minimum of friction and that studying one's employer (or teacher) and submitting gracefully to his peculiarities is frequently essential to promotion (or good grades).

The latter part of the paper discusses the general aims of en-

gineering training. It a student is to prepare himself to the maximum degree for a position in industry he must, on entrance to college, select his field of engineering within very narrow limits. The student is very rare who has the knowledge, either of industry or of himself, to permit of this and I don't think it would be to his advantage if he could; the training would be too narrow. Modern schools stress general training almost as much as the technical training. The present trend seems to be toward the elimination of many specialized courses, but giving more thorough training in the fundamental subjects, placing more emphasis on English, both spoken and written, and the inclusion of some work in the social sciences. Such a program prepares the student more satisfactorily for a life of general usefulness and gives him a wider choice of employment. In addition to this basic curriculum the student has time to elect a few specialized courses.

But suppose the student wishes to specialize still further. He may do this to some extent in one or more graduate years, but perhaps not to the extent desired by industry. Furthermore, as shown by Mr. Reid's questionnaire, the selection of courses is rarely the best possible for the work he eventually gets into. The whole tendency is to lengthen the college course considerably. Some schools have actually done so and others have increased the requirements to the point where the average student cannot finish in the allotted time. It seems to me that the ideal solution is for the student to enter industry at the end of, say, five years of college work. After one or two years of employment it will become evident whether the man, *and his employer,* could profit by giving him further training. If so, he could then return to college on a part pay basis or, better, he could attend a full or part-time school established by his industry. Some large concerns are operating somewhat similar schools at present. The smaller concerns could combine through trade organizations to finance central schools. Such a scheme is in line with the modern trend toward adult education and it has the advantage, over our present methods, that fitness of the candidate would be determined by actual experience rather than by academic tests and personal judgments. This same experience would indicate the type of training each man should have and he would get it after sufficient contact with industry to appreciate properly the details and implications of his studies. This idea may be criticized as seeming to pass the buck right back to the employer. If industry wants a better material it will have to pay for that improvement in one way or another. At present, as Mr. Reid says, we are probably spoiling many good plumbers and the method suggested above would seem to be a more efficient use of our resources, both of men and of money.

REPORT OF COMMITTEE ON RELATIONSHIPS BETWEEN JUNIOR AND SENIOR COLLEGES *

The Committee on Junior Colleges of the Pacific Southwest Section of the Society for the Promotion of Engineering Education has had as its main activity during the five years of its existence, the obtaining of information relative to the function of the Junior College in engineering education. Through the work of the Committee and from the papers presented at meetings of the Section considerable pertinent information relating to faculties, curricula, equipment and methods of student guidance has been obtained. Appended to this report is a list of the papers presented before the annual meetings of this Section since 1933.

The altered pattern of the lower division engineering curricula as generally approved by our Society and now widely accepted by engineering colleges with its increased emphasis on the fundamental principles of mathematics, chemistry and physics and with some training in cultural and humanistic subjects, makes possible the more effective functioning of the Junior College in lower division engineering training. Shop work requirements during this period of instruction have been largely abandoned with the result that special and expensively equipped laboratories are no longer needed. These changes permit the Junior College more readily and creditably to offer pre-professional engineering instruction.

The training of student engineers close to their homes during this lower division period of instruction provides an opportunity for eliminating, or diverting, those not qualified for an engineering career before heavy investments have been made in their education. Thus the well organized and administered Junior College may become an economical component of the professional engineering educational system. On the other hand, low standards contribute to waste.

That such lower division training may be provided on an acceptable basis is shown by data collected from three Senior Engineering Colleges in California and eight Junior Colleges, representing the performance of junior college transfers in comparison to the performance of all upper division students during their junior year. (See Table I attached.)

These data indicate that transfers to upper division work from

* Presented at the Sixth Annual Meeting of the Pacific Southwest Section, S. P. E. E., Los Angeles, December 29, 1937.

PERFORMANCE OF JUNIOR COLLEGE STUDENTS IN SENIOR COLLEGES OF ENGINEERING

1932–1936 Incl.

Senior College No.	1		2‡		3		Total Transfers for 1932–36 Incl.
Gen'l. Class Av. Senior Col.	1.31*		2.40†		1.21†		
Junior College No.	No. Student Transfers	J. C. Transfer Class Av.*	No. Student Transfers	J. C. Transfer Class Av.†	No. Student Transfers	J. C. Transfer Class Av.†	
1	56	1.44	7	2.40	11	1.60	74
2	41	1.02	21	2.30	17	1.20	79
3	78	1.00	1	3.20	0		79
4	85	1.16	0		0		85
5	38	1.13	2	2.25	10	0.80	50
6	15	0.84	2	2.30	5	0.75	22
7	20	1.18	2	2.20	0		22
8	10	1.22	0		2	1.60	12
Totals	343		35		45		423

* 1st Semester Class Average, Junior Year for students entering as Freshmen.

† General Class Average for Entire Junior Year.

‡ No. 2 Senior College grades; A = 4; B = 3; C = 2 and D = 1. To be comparable to senior colleges 1 and 3 subtract 1 from the grade point average shown.

some Junior Colleges may even excel the upper division records of students who had their lower division training in the Senior College. On the other hand, the records of transfers from other Junior Colleges consistently fall below those who have had their entire training in the Senior College. The complete data, much of which could not be included in this report, indicate rather forcefully the lack of uniform standards of performance among the 42 schools studied. In general, however, this problem is of more importance in the larger schools as is indicated from the complete data for the period 1932–36, which show that 10 out of 42 of the schools have provided 71 per cent of the Junior College transfers at one Senior College; 2 out of 8 schools supplied 80 per cent at another, and 3 out of 21 schools supplied 53 per cent at another. In each case the same leading schools were included at all three institutions as heavy contributors.

A consideration of these and other factors by the Committee has lead it to believe a definite conclusion should be reached from the informative phases of this work, in order that a constructive program for the promotion of engineering education of Junior College

scope may be undertaken, relating to lower division pre-professional training only regardless of where it is offered.

This Committee believes that standard lower division engineering curricula are now established and should be recognized as a part of the undergraduate engineering educational program. It further believes that sufficient data are collected to show that certain Junior Colleges are successfully performing this function and that the future will show a continually increasing percentage of pre-professional engineering students coming from such institutions.

The Committee has broadly considered the general characteristics of, and facilities for, engineering study in several Junior Colleges and has sought to determine the factors which have led to success and those which have resulted in failure as brought to light by the data available. In the light of these comparisons and considerations, the Committee wishes to submit, for endorsement by the Section, the following recommendations:

1. *Teaching Qualifications.*—The teaching qualifications of instructors in engineering subjects depend, in addition to adequate basic engineering training and teaching experience of collegiate grade, on successful experience in professional engineering practice, and the maintenance of professional engineering contacts. (These requirements are even more important in the Junior College than in the Senior College where opportunities for professional experience and contacts in the latter are available through research programs. Our Society has devoted much thought and time to effective teaching but specific reference to a recent paper seems appropriate to illustrate this point. A. A. Potter, Dean of Engineering, Purdue University, in his paper on Effective Teaching, Vol. 28, No. 2, JOURNAL ENGINEERING EDUCATION, October 1937, states: "The good teacher is a master of the subject he teaches. . . . One whose education has been limited only to the subjects that he is trying to impart is unfit to occupy a post at an institution of higher learning; the teacher must broaden his vision through advanced study and experience. . . . Graduate study, engineering experience, reading, travel and a keen interest in young people are essential prerequisites. A person who has never worked for pay in a shop, plant or on a construction job and who has never rubbed elbows with workers unskilled as well as skilled lacks essential experience for engineering teaching.")

2. *Segregation of Students.*—In the engineering and pre-engineering subjects, it is highly desirable if not imperative that students who are preparing for upper division work should receive their instruction in entirely separate and different classes from those for the terminal-type student and that the pre-professional

engineering group should be limited to those meeting accepted college entrance requirements.

3. *Recognition of Engineering Departments.*—The administration of the Junior College should give proper recognition to, and should properly evaluate, the work of the engineering departments. This implies:

a. Permanency of policy toward the work.
b. Provision for equipment in keeping with the professional nature of the instruction.
c. Teaching loads which will permit distinctly collegiate type of instruction and the maintenance of professional contacts. (Because of the lack of laboratory assistants and unavailability of qualified readers in the Junior College, instructors should, in general, be assigned teaching loads lighter than those assigned to teachers in institutions where such aids are furnished.)
d. A student counseling system at least the equal to that afforded lower division students in regular four year engineering colleges.
e. Appropriate salaries which will secure and retain men who are representative of the professional engineering field.

4. *Costs.*—The costs per student in lower division engineering instruction should be predicated on comparable costs of similar instruction in the four-year institutions. Such costs should not be limited to the per capita cost of educating the general Junior College student.

Respectfully submitted,

H. B. WALKER, *Chairman*
GEORGE A. GALLAGHER, ARTHUR G. GEHRIG,
FRANKLIN O. ROSE, DANIEL E. WHELAN, JR.

LIST OF PAPERS PRESENTED BEFORE THE PACIFIC SOUTHWEST SECTION S. P. E. E. ON JUNIOR COLLEGE MATTERS

APPENDIX I

December 1933: UNIVERSITY OF SOUTHERN CALIFORNIA

The History of Engineering Education in the Junior Colleges of California, by Franklin O. Rose, then of the Modesto Junior College.

Aims and Objectives of Semi-professional Engineering Courses at Los Angeles Junior College, by R. H. Walters, of the Los Angeles Junior College.

Lower Division and Completion Engineering Courses in the Smaller Junior Colleges, by Arthur C. Terrill, of the Fullerton District Junior College.

Junior College Problems of the Thirteenth Year Engineering Curriculum, by Arthur G. Gehrig, of the Pasadena Junior College.

December 1934: UNIVERSITY OF CALIFORNIA

Can the Junior College Give the Necessary Work of the Engineering Course, by Ward H. Austin, of Marin Junior College.

December 1935: STANFORD UNIVERSITY

Examinations in the Junior College, by Donald B. Pheley, of the Los Angeles Junior College.

The Engineering Curriculum in Junior Colleges, by T. D. Thorpe, of the Sacramento Junior College.

December 1936: UNIVERSITY OF ARIZONA

Teaching Loads of Engineering Teachers in Junior Colleges, by Daniel E. Whelan, Jr., of Loyola University.

Student Advisers for Junior College and University Students, by H. B. Walker, of the University of California.

PHYSICAL THEORY IN ENGINEERING LANGUAGE

By C. A. NORMAN

Professor of Machine Design, Ohio State University

Summary.—The function of the engineer as a logical intermediary between science and the workaday world has often been emphasized, but engineers in general have not taken this function very seriously. This may have been fortunate in the past, since the basic conceptions in nineteenth-century interpretation of nature have now been found to be completely erroneous. The new scientific conceptions flowing from electronics, wave theory of matter, and theory of relativity are now however penetrating not only technology and science, but also philosophy, religion, and even everyday life, in such a sweeping way, that the task of their proper presentation and application is becoming one of most far-reaching importance. Engineers, who in contrast with the vast majority of citizens, are trained to understand scientific and mathematical fundamentals, and yet have to have the ability to deal intimately even with common laborers, should begin to take their task as logical intermediaries and interpreters seriously. An attempt is here made to present some main findings of twentieth-century science in scientific and mathematical terms, yet with such simplicity that engineers who are interested should not find it difficult to understand them.

1. *The Engineers in a Scientific World.*—At graduation exercises and annual banquets engineers have been in the habit of flattering themselves, or being flattered, by the statement that they occupy a pivotal position as intermediaries between science and the everyday world. They, being mathematically trained, can understand what science has to convey; and on the other hand, being practical men and compelled to translate their ideas into words intelligible at times even to a day laborer, they are the logical interpreters of scientific findings, and their meaning, to people at large.

Now this is an important task in view of the way in which science more and more penetrates into our daily lives and influences our thinking. Yet, it is not often that engineers in the past have taken this task seriously. Quite on the contrary, the majority of them have been glad to forget most of their science and mathematics promptly upon graduation.

Let us say at once that this may have been a fortunate thing

as far as nineteenth-century science was concerned. For nineteenth-century science was an *atomistic* science. The laws of Dalton and Gay-Lussac, the hypothesis of Avogadro, with which all engineers were familiar, led to the conception that the world was made up of un-created, indestructible, material particles, governed in their relative movements and mass effects merely by the laws of chance. The climax to this came when Boltzmann in 1878–79 identified entropy with the probability of molecular states. The second law of thermodynamics, the increase of entropy in all spontaneous natural processes, on this basis simply meant that the world was proceeding inexorably from less probable to more probable molecular arrangements. And since the most probable arrangement is uniform chaos, it meant that under the laws of physics the material world was heading toward that dead equilibrium which the Germans call the "heat death."

Take then the theory of evolution in its extreme Darwinian form: The first organic molecule appears by chance combination. From it all other organic forms develop by chance variation and the maintenance of the fittest in a free and unordered struggle for existence. The law of probability governs even the appearance and destiny of man. That Tennysonian "far-off, divine event" toward which man moves with the rest of creation, is merely all-inclusive, uniform chaos. A gloomy outlook, one will surely say; not very inspiring to moral stamina, or self-immolation for great human ends. It may have been well, as we said, that engineers, the leaders of everyday industrial enterprise, did not bother much about these things.

There is, however, good reason to expect that this aloofness neither can, nor should, be maintained much longer. In the nineteenth century-engineering engineers dealt almost entirely with gross phenomena—pressures, temperatures, volumes, current intensities, voltages, all of which were for technical purposes connected by simple mathematical formulas, requiring no understanding of underlying phenomena either for their derivation, or their use. How many engineers had any use for the kinetic theory of gases? How many had to bother with Maxwellian field theory? How many chemical engineers were bothered with the possibility that the idea of indestructible atoms, with which they worked all the time, might knock current religions and moral philosophies into a cocked hat?

With the advent, however, of electronics, of radio telegraphy, of X-rays, and transmutation of matter, the picture has radically changed. Engineers dealing with these things are face to face with ultimate realities of matter. In increasing measure they are trying to acquire an education which enables them to understand

these things. Engineers with Ph.D. degrees are getting common. Technical research laboratories maintain men whose one yearning is to penetrate as deeply into the secrets of nature as do theoretical scientists. Ambitious theoretical treatises begin to emanate from such men. Discoveries of the most far-reaching influence on our interpretation of the world are made in engineering institutions. It might have been an accident that that most crucial experiment from which flows the Theory of Relativity, the experiment of Michelson and Morley, was carried out in an American engineering school, Case School of Applied Science, as far back as 1887. It is, however, no longer an accident that that equally crucial experiment which proves that matter can behave as vibratory energy, the experiment of Germer and Davisson, was carried out some forty years later in the Bell Telephone Laboratories, the laboratories of a commercial concern. Such matters had then become matters of practical engineering interest.

In England an eminent automotive and aeronautical engineer, F. W. Lanchester, has written a whole book on relativity and has had it published by a leading technical publishing house. In this country the chief engineer of a leading automotive concern likes nothing better than scientific theorizing and privately supports research having to do with the origin of life. Common, ordinary machine designers begin to acquire an understanding of the theory of vibrations, and leading ones become mathematicians capable of handling the most abstruse scientific theory. Even industrial engineers become infected and apply the theory of probability to their ideas of profitable accuracy. Commercial concerns hire mathematicians to forecast the trend of business conditions. We begin to see that not only abroad, but even in this hard-headed, practical America science is breaking into our everyday technical life in a startling fashion.

With such infiltration of the scientific spirit into our technical processes, and into products of these processes which are often used wholesale by every Tom, Dick, and Harry in the land, it is certain that the dicta of science will in increasing measure affect our fundamental attitude to the world and to things in general. It is fortunate that now, when this is happening, the scientific interpretation of nature has veered completely from that atomistic nineteenth-century interpretation which was so devastating to all truly moral outlook. Hence, instead of religion now being hostile to science, we find ministers preaching elatedly that science has demonstrated that matter is energy, and not material at all. We find philosophers claiming that the Heisenberg doctrine of indeterminancy is the scientific demonstration of the possibility of free will, and hence of legal responsibility. We find the expansion of

the universe, as deduced from the red-shift of the spectral lines from distant nebulæ, leading scientists to set definite dates for the creation of the world and even to give symbolic descriptions of how the creation took place. So the English physicists Jeans, Milne, and Eddington.

Now all this is to the good, for history shows a very close parallelism between a people's religion and their economic and political life. People who believe in an arbitrary and despotic god are apt to be ruled by an arbitrary and despotic autocrat. People who worship merely animal forces and natural phenomena are apt to be swayed by animal passions and cupidities also in their social life. Anarchistic and nihilistic world conceptions may breed anarchistic and nihilistic politics and economics also. On the other hand, a belief in a generated and ordered universe ruled by a God of love and compassion, will in time no doubt produce societies organized somewhat in this image. All this we have in mind to examine more closely in a succeeding article. Here we only wish to say that all these ideas, now spreading abroad from scientific sources, may result in nothing but nebulosity and misunderstanding if they are propagated almost exclusively by people who from lack of training in mathematical and scientific thinking cannot possibly know what the words they are using really mean.

It is here that the engineers can bring help. They occupy a key position not only as persons who are trained in scientific expression and reasoning, yet, at the same time find their problems in the workaday world, but also because as industrial executives they are in contact with policy forming bodies on the one hand and the laboring masses of the people on the other hand.

An economist, Thorstein Veblen, has in a famous book * flatly stated that only the engineers are capable of operating modern industrial society. Yet, he also complained that they rarely have taken this task seriously, but have allowed themselves to be guided and dictated to by groups with far less inherent competency than they have.

It is time that this be changed. Engineers are very rarely radicals and revolutionaries. They do not go off half-cocked. There is little chance that they will cause havoc and chaos if they decide to attempt to guide things a little more than they have been doing. Their first step will merely be to try to inform themselves calmly and dispassionately what "it is all about." It is to render some help in this direction that this article is written. We shall try to set forth in as simple a language as possible, yet mathematically wherever necessary for precision, what those fundamental findings of twentieth-century science are which are likely to affect

* "The Engineers and the Price System," Viking Press.

our basic attitude to the universe. In this article we shall confine ourselves to physical science only, and leave biology for eventual later consideration. We shall not go into things which, though scientifically curious and interesting, may yet tend to complicate and obscure, rather than clarify, the main issue.

2. *The Michelson Morley Experiment.*—The real starting point for our modern outlook is undoubtedly the Michelson-Morley Experiment, which as we have said took place in the Case School of Applied Sciene in Cleveland.

Michelson set out to measure the velocity of the earth relatively to the *ether,* that substance which, though nobody had been able to suggest a mechanical model for it, was yet thought to fill the universe and transmit by vibration the radiant energy from star to star. He used the apparatus shown schematically in Fig. 1. A source of

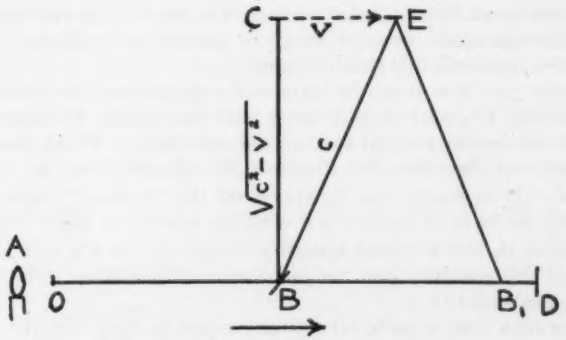

FIG. 1. Michelson-Morley Experiment.

light A transmits light rays into a frame $OBCD$. An inclined mirror at B lets some of the rays pass through to another mirror D, from which they are reflected back, and deflects others along BC to a mirror at C. The rays reflected from C meet those from D at B and a combined ray may be deflected sideways for observation. If BD is exactly as long as BC, and if the apparatus stands still, there should be coincidence of phase in the combined ray. Suppose however that the frame is moving in the direction of BD with a velocity v. The ray deflected toward C at B will have to travel along the path BE to reach the mirror at C. It travels cross-lots and requires less time to get back to the mirror B than the ray which has to catch up with the receding mirror at D. It should therefore be out of phase with the one from D and there should be interference phenomena. From these it should be possible to compute v. If the frame is oriented so that v is in the direction of the

motion of the earth through the ether, the velocity of this motion could be determined. But no effect even approaching the estimated one was found. The conclusion had to be drawn that light covered the longer distance *BE* as fast as it covered the shorter distance *BC* and the startling law was arrived at:

The relative velocity with which light, or as it has later been found out, any radiant energy, reaches a body is independent of the state of motion of that body. The light velocity c, or the rate of communication of radiant energy from one body to another, is *a universal constant,* independent of the state of relative motion of the bodies.

In other words, our everyday notions of space and time relations, from which the idea of velocity is derived, are in error. The error is insignificant in connection with the relative motions of gross material bodies, but we shall find it tremendous in connection with that most fundamental process, the rate of energy transmission through space, or in general, in connection with any relative velocities approaching that of light.

To see just how great the error is, let us assume that the distance *BE* in Fig. 1 is such that it takes just one second to cover it. It is then numerically equal to the light velocity c. From the simple geometry of the case the distance *BC* should then be equal to $\sqrt{c^2-v^2}$. It is found that to represent the "cosmic" relations accurately we have to operate not with the velocity v as we ordinarily determine it, but with the quantity $vc/\sqrt{c^2-v^2}$, or $v/\sqrt{1-v^2/c^2}$. We see that this quantity has the peculiarity of becoming infinite when v becomes equal to c.

The idea that a material velocity equal to that of light in "its cosmic aspect" really represents an infinite velocity is due to our brilliant English confrere F. W. Lanchester.* It has not been accepted by scientists, as far as I know, yet it may be helpful in our engineering or philosophical interpretation, although Lanchester's proof of it by graphical methods is not exactly simple. It prepares us immediately for the next consequence, namely that *no material body can be speeded up to the velocity of light.* This has been amply verified through experiments on flying electrons by Kaufmann, and others. Kaufmann's work was published in 1901 to 1906.

In going further into this matter it is well to realize that velocity from the theoretical point of view may be merely a mathematical abstraction, not a fundamental reality of being. This was quite clear to Newton who formulated his second law of motion not in terms of velocity, but in terms of *momentum*: "The change of

* See F. W. Lanchester, "Relativity," Constable, London. Lanchester's "cosmic velocity" is, however, set equal to $\int dv/(1-v^2/c^2)$ (see p. 177).

momentum is proportional to the impressed force." Newton defines momentum as consisting of two components, mass and velocity. This of course is very natural in connection with the motions of material bodies, and was particularly convenient during the nineteenth century when mass was supposed to be constant and indestructible. We then said that the force was proportional to the change in velocity (in unit time), and this velocity, as well as its increase, were easily observed and measured quantities.

It was no wonder then that our engineering dynamics were dominated by this idea. Yet, in the dynamics of fluids we dealt with the more fundamental entity. For instance, the force derivable from turbine buckets is proportional to the momentum imparted per unit time. In this case the mass passing per unit time is the variable, more often than the velocity change. We find, however, that Newton's second law is applicable even when there is no mass at all. Light—pure wave motion—has apparently no mass. Yet, it exerts pressure when falling on a material body, and this pressure is found to be proportional to the change in momentum as derived from energy relations.

Recognizing then, that the mass may be just as variable a component of the momentum as the velocity, let us see what conclusions may be drawn, if we apply to it, rather than to the velocity, the modification factor $\frac{1}{\sqrt{1-v^2/c^2}}$. Call the mass at rest m_o and the mass at a velocity v, m_v. We would have

$$m_v = m_o(1-v^2/c^2)^{-1/2} = m_o + \frac{m_o v^2}{2c^2} + \cdots,$$

the higher powers in the binominal development being left out since ordinarily v/c is so small as to make them negligible.

We come to the conclusion that mass increases with the velocity and that the increase is equal to the *kinetic energy resulting from the velocity,* divided by the square of the light velocity. If we made our measurements in terms of cosmic realities and made the universal constant c our unit of velocity, the mass increase would simply equal the kinetic energy. Multiplying by c^2 we find $m_v c^2 = m_o c^2 + m_o v^2/2$, that is, the kinetic energy due to v simply adds itself to a term $m_o c^2$, a term equal to the *vis viva,* or twice the kinetic energy of the rest mass m_o, moving with the light velocity c. We are tempted to conclude that mass is nothing else than energy.

The question now comes what is the more fruitful thing to do; Conclude with our colleague Lanchester that the real "boundary velocity" in the universe is infinite, although to our finite observations it appears as if it were the light velocity c, or conclude that

mass is essentially energy. It is possible that for certain aspects of cosmic interpretation Lanchester's ideas may prove valuable. Yet, scientists have decided for the latter alternative, and we shall find that it enables us to order and approach natural phenomena in a manner very fruitful for practical understanding and control.

As an example, we now believe that atoms are built up of two kinds of units—negative electrons, and positive protons, the former circling as planets around the latter as central suns. If this is so, heavier atoms should be simple multiples of the lightest atom, hydrogen. We find, however, that if we put the atomic weight of oxygen at 16 and helium at 4, the atomic weight of hydrogen is not unity, but 1.008. This is very easily explained if matter is energy, for four hydrogen atoms in "falling together" to form helium lose a certain amount of potential energy which passes out as radiation. It is now commonplace for science to talk about mass being continuously converted into radiation, and many observed cosmic phenomena can be explained on this basis. We have not so far observed the opposite phenomenon, the creation of atoms out of radiant energy. However, we shall see that there are now a multiplicity of observations proving both that vibratory energy can at times act as material particles, and that material particles can act as vibratory energy.

This leads us to a brief consideration of

Quantum Theory and Electronics.—Around the turn of the century Max Planck was wrestling with the problem of the distribution of energy in the spectrum of a radiating body, and entirely in the spirit of the nineteenth century hit upon the idea of applying probability theory to this problem. To do so he had to split up the "energy field," as a mere mathematical conception, in regions proportional to the frequencies, each region containing the amount of energy $h\nu$, where ν is the frequency and h a constant. He arrived at formulas which in a surprising way fitted the whole reach of energies and temperatures, and harmonized the conflicting formulas of Wien and of Rayleigh. The real meaning of the quantum constant h however remained completely unclear. But in 1905 Einstein used it in a startlingly concrete way for the explanation of the photo-electric effect, discovered earlier by Hallwachs, Lenard, and others. Metals subjected to light radiation emit electrons. The kinetic energy of these electrons, strange to say, is found to be proportional not to the intensity or total energy of the radiation, which merely determines the number of electrons emitted, but to its frequency. To explain this mystery Einstein suggested that the light came in in *quanta* or units, each of the energy $h\nu$, and that each quantum was able to knock out one electron, provided it had energy enough to carry the electron

beyond the bonds which held it to other electrons. If this disengagement work was small, as in the case of highly positive alkali metals, the kinetic energy of the emerging electrons would be practically equal to the quantum $h\nu$.

We then had the astonishing situation that light, without losing its vibratory character, could seemingly act almost as if made up of solid bullets. To these bullets were given the name *photons*.

Here then was a direct experimental proof that vibratory energy could act as material particles.

An even more concrete proof of this was given by A. H. Compton in 1922. If a moving billiard ball impinges on a stationary one and sets it in motion, the law of the conservation of energy demands that it loose some of its kinetic energy to the latter ball, and that in consequence it must slow up. Now, if the impinging ball is a photon, its loss of energy should manifest itself as a reduction of frequency, since its energy is equal to $h\nu$, a constant times the frequency. And this Compton found to be the case when he let X-rays, that is vibratory energy of high frequency, impinge on electrons (*Compton effect*).

It had then been proved that vibratory energy could behave as matter. In order, however, completely to equalize matter and energy it was necessary to show also that matter could behave as vibratory energy. The impetus to that was given by de Broglie * who in a doctor's thesis of 1924 proposed that the kinetic energy W of a flying particle ought to be put equal to $h\nu$, so that it would represent a wave frequency W/h. This idea was later worked out much more fully, but also in a much more abstract manner by Schroedinger, as well as by de Broglie himself.

Of more importance, perhaps, to us hard-headed engineers is the fact that Germer and Davisson in the Bell Telephone Laboratories and G. P. Thomson in England have put the vibratory theory of matter to test by producing diffraction and interference rings of electrons impinging on nickel crystals or thin metallic films. These phenomena can certainly be produced by vibratory motion only

By these experiments the nineteenth-century idea of matter as consisting of hard, indestructible, everlasting particles, has been completely demolished. We now must take the attitude that matter is essentially vibratory energy of a most fleeting and variable kind. Space forbids us here to go into this matter in detail. For those who wish a picture we may say that the most plausible picture at the present time is that the fundamental material particle is the agglomeration of waves of somewhat differing frequency. Where these waves agree in phase we have the phenomena of the particle. The boundaries of the particle are where the waves

* See also, Louis de Broglie, "Wave Mechanics," Dutton.

cancel out. These boundaries are more sharply defined when there are considerable differences between the frequencies of the constitutent waves; but then the energy, or mass, of the particle, which is proportional to the frequency, is somewhat uncertain. On the other hand, if there is but little difference in frequency the particle is very much spread out, its "location" is uncertain; but then its energy or mass is much more closely defined. This is one formulation of the uncertainty principle of Heisenberg. Location and momentum (or velocity) cannot be exactly defined at the same time. The more exact we make one, the more uncertain is the other. The product of the momentum "range" and the location "range" for an electron is equal to, or greater than, the quantum constant h.

The Course of Events

We have so far dealt with what matter is. This is very important. Yet, even more important, perhaps, is the question of the nature of the laws which govern the course of events. In nineteenth-century physics this law was the law of probability, the law of the increase of entropy, the march toward the "heat death."

What law is it now?

Approaching the thing historically, we engineers may derive considerable satisfaction in noting that the starting point for it all is really nothing else than our old familiar Second Law of Newton, formulated, however, be it well noted, in its correct form: The change in *momentum* is proportional to and in direction of the force, impressed or exerted. In this form the law is applicable not only to mechanical phenomena, but to all physical phenomena, and it is applicable in relativity mechanics as well as in classical Newtonian mechanics.

It is, however, well for further developments to restate it in a somewhat different form. We call the forces produced by changes in momentum *inertia forces,* and we say that the inertia forces balance the external forces (Principle of d'Alembert). Engineers usually write $F = d(mv)/dt$. We shall here call the momentum p and write $F - dp/dt = 0$, F being the external force.

This reduces Newton's second law to an equilibrium equation and we shall make further progress by considering the various ways in which we can define the conditions for the simplest of all equilibria, namely that of rest. Take as an example the equilibrium of a pendulum. The equilibrium position may be defined in three ways:

1. All forces balance in this position.

2. The potential energy in this position is a minimum, consistent with the restraints imposed.

3. Slight displacements at the equilibrium position neither require, nor yield work (since the forces in this position are at right angles to the direction of the possible displacement).

Now in dealing with motion, we have three exactly similar equilibrium conditions. All we have to do is to include the inertia forces with the other forces acting.

However, in electrical phenomena, radiation phenomena, and many other, we often prefer to deal with potentials and energies, rather than with forces. Also we usually have numbers of points, or quantities of substances, to deal with rather than single particles. Hence there appear summations and integrals in our equations rather than simple point expressions. If the potential energy is $E_{\text{pot.}}$, the external force acting along a path in the direction q is $-\delta E_{\text{pot.}}/\delta q$. If the kinetic energy is $E_{\text{kin.}}$, then the momentum is $\delta E_{\text{kin.}}/\delta(dq/dt)$. This can easily be checked by differentiating the ordinary kinetic energy $mv^2/2$ and observing that $v = dq/dt$.

We can define the equilibrium conditions in motion by the principle of d'Alembert as above; we can also define it by the principle of virtual displacements, which states that the sum total of work done by the external forces and by the inertia forces is zero for small displacements from the actual path.

The equilibrium condition corresponding to minimum (or stationary) potential energy, however, can be made to take on a somewhat different form which has become of exceedingly great importance in modern physical theory, although in one form or another it has been known for some two hundred years. This is the *principle of least action.* By *action* is meant either the time integral of the vis viva, $2\int_{t_1}^{t_2} E_{\text{kin.}}dt$, or the space integral of the momentum, $\int_{l_1}^{l_2} p dl, dl$ being an element of the path. The principle of least action states that along the path followed by a phenomenon, these integrals are a minimum, or are at least stationary. This latter case corresponds to the case of a pebble which in rolling down a slope may stop on a ledge and not proceed clear to the bottom.

In modern physics these integrals are, however, not used as much as the integral of Hamilton $\int_{t_1}^{t_2} L dt$, where L is $E_{\text{kin.}} - E_{\text{pot.}}$, and is known as the *kinetic potential.* This integral also is a minimum along the actual course. The kinetic potential with its minus sign may look like a queer thing to engineers, who are more used to dealing with the total energy $E_{\text{kin.}} + E_{\text{pot.}}$. Yet, when we remember that the momentum *in*creases with increasing $E_{\text{kin.}}$ while

it *de*creases with increasing $E_{pot.}$, the minus sign is explained and the organic connection of L with the development of momentum at once becomes apparent.

In further attuning ourselves to the nature of action, we may consider the problem of the flight of a projectile, since this will make clear why the time enters into the problem as it does in the action equation. The path of a projectile in a vacuum from the point of discharge to the target, we may feel to be dependent only on the kinetic energy at the muzzle. However, if we wish to follow the path in detail, and be sure that it hits the target, elements of the path, or time, are evidently involved. The law of least action tells us that we can start with a low muzzle energy and reach the target over a long path, and after a long time, or we can start with a high muzzle energy and reach it over a short path and after a short time. In any case the path will be such that the sum total of energy times time element, or momentum times path element, that is the sum total of action, will be the minimum possible under the circumstances. What nature economizes is *action,* energy times time.

This recognition caused the original discoverer of the theorem of least action, Maupertuis, to grow almost panegyric about the perfection of nature. And in most recent times no less competent a scientist than Max Planck, the originator of the quantum theory, has used it to justify his belief in God and the purposefulness of nature.* For here, says Planck, we have a phenomenon the course of which is determined not by a cause at the beginning, but by the end sought. No matter how bungling we men are, physical nature hits its goals with the minimum expenditure of action. There is no question of chance here. Nature does this unerringly every time.

Now with this attitude the writer has no quarrel whatever. He is fundamentally just as religious as Planck is. Yet, if indeed it is true that we here stand face to face with the profoundest and most awe-inspiring mystery of nature, it is well that we investigate its character in all its phases to the full extent of our ability.

In this connection it is of extreme importance to consider the complete parallelism of mechanical and optical phenomena, already pointed out by W. R. Hamilton (1805–1865). We know that a light ray travels so as to reach a point in the shortest possible time. This now appears as a direct consequence of the law of least action, when the energy is constant ($\int E_{kin.} dt = \text{min.}$; *i.e.* $\int dt = \text{min}$). In homogeneous media, where the velocity of travel is constant, this means that it reaches its goal along the shortest path—a straight line ($\int v dl = \text{min.}$; *i.e.* $\int dl = \text{min.}$).

* Pamphlet, "Religion und Naturwissenschaft," Amb. Barth, Leipzig.

This parallelism was a curiosity to which the scientific world paid little attention for a long time. In fact, the whole theorem of least action was hardly referred to at all in ordinary physics.

All this has completely changed with the advent of the modern theory of matter. It was found that the Hamiltonian equations gave a wonderfully simple approach to the motions of electrons inside the atom; and in the wave theory of matter action is perhaps even more fundamental. In fact, Planck's universal constant h has the dimensions of action. It seems in fact to be the fundamental quantum of action. According to the theory of Schroedinger, the wave fronts that move through space are action fronts. In the cosmic theory of relativity action governs the natural tracks of energy and material particles through space and explains the influence of gravitation.

All this is extremely impressive; but just how does the action act? What is the machinery by which it accomplishes its ends? The answer it that it probably is through the action of vibratory interference. The waves which coalesce into a material particle cancel out along all tracks except that described by least, or stationary, action. There is then no question of "supernatural" guidance. Quite on the contrary, it looks quite natural that the waves which carry a material particle to a certain point must be those which fortify one another toward this point, not those which cancel out.

From the mechanical point of view we might also make the matter more palpable by saying that the path of least action is the path of least resistance. It is an equilibrium path. Any other path would mean that more "effort" would have to be expended either as kinetic or as potential energy to reach the goal. It is the most efficient, but as such also the "laziest" path. The energy simply travels where it can travel most easily. We should not imagine any alert little demons riding on the atoms and guiding them to their goals by marvels of piloting skill. Nevertheless the result is perfect harmony between modern engineering efficiency methods and the natural ways of nature. The principle of both is maximum results with minimum effort. Nature, however, also has a "creative urge." It is extraordinarily anxious to release pent up potential energy. It does not rest before this energy is spent as completely as the circumstances permit. But it produces maximum change and transformation in so doing.

Identification of Time and Space.—In identifying matter with energy and studying the supreme law that governs the physical universe, we have acquired a new "feel" toward what nature is. We now sense matter as energy, pent up or released, we sense the cosmos as swayed by a creative urge, a yearning to produce trans-

formation and motion. We have cited the name of at least one great scientist who from this interpretation acquires a fundamentally religious attitude to the world. We could cite the name of many others holding religious views—Whitehead, Weyl, even Einstein, not to mention the fact that Newton himself was extremely religious.

The most sweeping and majestic conception of what the world is like from the "divine" point of view is, however, given by conception of the world as four-dimensional, with *time* as a fourth, imaginary, dimension. This development is due preëminently to Minkovski (1909).

Minkovski's idea is that the world should be described as *events* the distances between which we perceive partly as space, partly as time. Every observer, however, splits up the space-time relations in a different way dependent on his state of motion, but all observers find the same value for their velocity of light and the action quantum. These are the great invariant realities of nature.

The theory of Minkovski reduces the motion problems of nature to problems simply of four-dimensional geometry. Events lie on "natural tracks" or geodesics in the four-dimensional continuum. These tracks are distinguished by maximum or minimum properties, that is, their length is not changed by small displacements.

In a world of this character real existence of course requires a certain extension in the time dimension just as well as in the space dimensions; just as in the three-dimensional world an area without thickness does not represent real bodily existence.

We can from this point of view readily see why action, that is energy times time, assumes a more basic character in the fundamental law of nature than does energy alone. Energy or mass alone is a mere abstraction. Real existence requires also a certain duration in time.

This, of course, when we come to think of it, is merely common sense and we should not have needed Minkovski's abstruse theory to realize it. Men, however, often grope on devious ways to attain clarity of outlook. It is as climbing a mountain from the side where we first happen to strike it. When we come to the top we realize that a much easier approach might have been possible, and it is only from there that we fully grasp the nature of the landscape in which the mountain is situated. Yet, if we had not started to climb where we happened to hit the declivity, it is possible that we should never have ascended that summit at all. We should have remained in the valley and in the shadows.

The theory of relativity and the Minkovski theory of a four-dimensional world lead to some strange ideas of simultaneity, of

variation of length and time measurements with the velocity of the observer, etc. Some very keen thinkers, among them Dr. Alfred North Whitehead, whose superior competence as a mathematician and a philosopher is not to be denied, do not agree with Einstein in his ideas of simultaneity and other things. It is much too early to say categorically what our final world picture will be like and what the true inwardness of nature is. It has been said that the advent of the 200-inch telescope now in the making may change our ideas of the universe at large quite radically. Yet, it is important to know that prominent physicists and mathematicians like Eddington, Jeans, Whitehead, Weyl, and others find a fundamentally religious attitude entirely compatible with their scientific ideas; that the new ideas of matter as energy and action give a live, and even 'human,' touch to nature that it was entirely lacking in nineteenth century conceptions; and that the new four-dimensional interpretation of the universe gives it an aspect of grandeur and poise, which is apt to inspire a feeling of awe and reverence even in scientists who have no formal religion.

ENGINEERING ECONOMY PAGE

Engineering Economy concerns the selection between two or more engineering designs or projects planned to accomplish a given purpose.

EDMUND D. AYRES, University of Wisconsin, *Editor*

Every graduate of every engineering school should be familiar with the question: "Will it pay?", have a firm grasp of the arithmetic of engineering economy, and a consciousness of costs which will make him ever mindful that an engineer is a man who can do for one dollar what any bungler can do for two.

EDMUND D. AYRES, University of Wisconsin, Editor

EDITORIAL COMMENT

This issue of the Engineering Economy Page closes a year of effort to make this particular spot in each month's journal a point of interest to not only teachers of subjects relating in some way to engineering economy but to all interested in engineering education. This first year has been a job of getting started. Not all who have sent in copy have had a chance to get into print yet. In the face of this it was believed desirable to introduce during this first year at least one engineering economy problem for discussion. What features do you suggest for next year that will build reader interest?

THE PROBLEM OF REPLACEMENT ECONOMY

As was brought out by Mr. Newhouse in one of his early criticisms of the handling of the replacement problem at the time the well known Shepard-Hageman formula was given to industry in 1925 and again in his statement introducing this problem on this page last month, a great deal of emphasis is still put upon the matter of unamortized value. Is it true that a solution of such a problem taking into account unamortized value can be shown to have an indestructible equivalence with a sunk cost solution of the same problem? What do our readers think of the following demonstration?

A small steam engine operated factory water supply plant had been operated for 10 years, when an arrangement with a nearby electric power supply made an electric pumping plant feasible and sufficiently reliable for installation. The old steam plant had cost $5,000 and a new electric plant complete was estimated to cost $6,000. The operating and maintenance costs of the electric plant were estimated to just halve the $2400 a year expense for the old plant. Taxes and insurance would be $50 per year for the old plant or 2% of the estimated value for the new plant. The old plant had been estimated to have a life of 20 years and straight line depreciation had been used. The book value after 10 years on this basis was $2500. Inquiry brought out that the best second hand value obtainable upon any proposed sale of the old plant would only amount to $500 when the cost of removal was taken into account. A life of 20 years was predicted for the new plant. If the industry requires a return of 15 per cent on its investment in order to justify the change, should the new electric plant be purchased?

	Annual Costs			
	Recognizing Unamortized Value		Sunk Cost Solution	
	Old Plant	New Plant	Old Plant	New Plant
Operation and maintenance..	$2400	$1200	$2400	$1200
Taxes and insurance	50	120	50	120
Depreciation	250	300	50	300
Book loss on steam plant charged to electric plant over remaining life period of steam plant		200		
	$2700	$1820	$2500	$1620
Savings in favor of the new plant		$880		
% return on extra investment		16.0%		

CIVIL ENGINEERING DIVISION

1. SUMMMER CONFERENCE ON STRUCTURAL PRACTICE

A Summer Conference on Structural Practice will be held at the Armour Institute of Technology, Chicago, Ill., June 20–23, 1938.

PROGRAM

Monday, June 20

Morning Session: Armour Institute of Technology, T. D. Mylrea, Chairman

8:30—Registration.
9:40—Welcome: H. T. Heald, Dean, Armour Institute of Technology.
9:45—(1) Details of Forms: J. H. Banker, Portland Cement Association.
10:45—(2) Design Practice as Contrasted with Theory: T. F. Collier, Regional Structural Engineer, Portland Cement Association.
12:30—Luncheon: Compliments of Portland Cement Association.

Afternoon Session

1:30–5:00—Inspection Trip: Concrete Building and Bridge Construction in the Chicago Area.
Bus furnished by the Portland Cement Association.

Tuesday, June 21

Morning Session: American Bridge Company, Gary Ind., W. A. Oliver, Chairman

8:35—Train from LaSalle Street Station to Gary, Indiana, American Bridge Company Plant. Train fare, 55c.
9:00—(1) Opening Remarks: C. Earl Webb, Division Engineer, American Bridge Company.
9:20—(2) Estimating: F. M. Highly, Cost Department, American Bridge Company.
10:00—(3) Detailing: C. J. Kennedy, Engineer, Gary Plant, American Bridge Company.
10:45—(4) Fabrication: J. C. Augsburger, Assistant Manager, American Bridge Company.
11:30—(5) Erection: H. C. Hunter, Assistant Vice-President in Charge of Erection, American Bridge Company.
12:30—Luncheon: Compliments of American Bridge Company.

Afternoon Session

1:30–4:30—Inspection Trip: Gary Plant and Drafting Rooms, American Bridge Company.
4:30—Train to Chicago: Fare, 55c.

Wednesday, June 22

Morning Session: Armour Institute of Technology, H. C. Boardman, Chairman

8:30—(1) Estimating: Ralph Green, Chicago Bridge and Iron Company.
9:30—Detailing: A. W. Seels and F. L. Goldsby, Chicago Bridge and Iron Company.
10:30—(3) Fabricating: C. S. Pillsbury and O. A. Bailey, Chicago Bridge and Iron Company.
11:30—(4) Erection: C. W. Hines, R. K. Dupee, and F. L. Wurst, Chicago Bridge and Iron Company.
12:30—Bus to Plant furnished by Chicago Bridge and Iron Company.
1:00—Luncheon: Compliments of Chicago Bridge and Iron Company.

Afternoon Session

2:00–5:00—Inspection: Chicago Bridge and Iron Company Plant and Drafting Rooms.
6:30—Dinner: Informal, Ladies cordially invited. Speaker: Dr. T. C. Poulter.
Subject: The Second Byrd Antarctic Expedition in the Field. Illustrated by moving pictures.

Thursday, June 23

Morning Session: Armour Institute of Technology, Frank Kerekes, Chairman

9:00—(1) Functional Design in Steel: Henry Penn, District Engineer, American Institute of Steel Construction.
10:00—(2) Planning of a Large Building in an Architect's Office: V. O. McClurg, Chief Structural Engineer, Holabird and Root, Architects, Chicago.
11:00—(3) History of Chicago's Bridges: Clarence S. Rowe, Engineer of Bridge Construction, City of Chicago, Engineer's Office.

Afternoon Session

12:00—Luncheon en route to Michigan Avenue Bridge over Chicago River where boat trip starts.
1:15–4:00—Boat trip up Chicago River: Compliments of City Engineer's Office. Trip in charge of Mr. Forest Field, Designing Engineer, Bridge Department, City of Chicago.

Committee on Arrangements

C. O. Dohrenwend, Armour Institute of Technology
F. W. Garran, Dartmouth College
L. E. Grinter, Armour Institute of Technology
H. T. Heald, Armour Institute of Technology
Frank Kerekes, Iowa State College
T. D. Mylrea, University of Delaware
W. A. Oliver, University of Illinois
Fred L. Plummer, Case School of Applied Science

2. REGIONAL CONFERENCE OF SURVEYING AND MAPPING TEACHERS

A Regional Conference of Surveying and Mapping Teachers is to be held September 5–8, 1938, at the University of Louisville, Louisville, Kentucky.

TENTATIVE PROGRAM

Monday, September 5 (Labor Day)

1:00– 4:30 P.M.	Registration, reunion, get-together and smoker at the Speed Scientific School, the College of Engineering of the University of Louisville, Belknap Campus, Louisville, Kentucky. For early arrivals local sight-seeing tours will be arranged for those caring to make them.
5:30– 6:30	Motor convoy to Otter Creek Camp (32 miles from campus).
7:15– 9:00	Welcoming Dinner to Conference Representatives. The Rainy Lake National Surveying Teachers Conference, J. S. Dodds, Iowa State College. The Rensselaer Regional Surveying Teachers Conference, H. O. Sharp, Rensselaer Polytechnic Institute. Entertainment to be arranged.

Tuesday, September 6

7:00– 7:45 A.M.	Breakfast.
8:30–11:30	First Formal Session. W. B. Wendt, University of Louisville, presiding.
8:00	Paper. State Wide Coördinate Systems. H. W. Hemple, U. S. Coast and Geodetic Survey.
8:30	Discussion, Phillip Kissam, Princeton University.
9:00	Discussion, George H. Dell, University of Illinois.
9:30	Paper. Local Coördinate Systems. E. F. Coddington, Ohio State University.
10:00	Discussion, A. H. Holt, Worcester Polytechnic Institute.
10:30	Paper. Standard Datums and Recent Readjustments of Control Surveys, Representative U. S. Coast and Geodetic Survey.
11:00	Discussion, Capt. Miles Reber, Corps of Engineers, U. S. Army.
11:30	Adjourn.
12:00– 1:00 P.M.	Luncheon.
1:30– 4:30 P.M.	Second Formal Session. M. W. Todd, Purdue University, presiding.
1:30	Paper. European Surveying Instruments and exhibit of European Surveying Instruments, E. F. Coddington, Ohio State University.
2:15	Paper. American Made Surveying Instruments and exhibit of modern American made instruments, H. M. Dibert, W. & L. E. Gurley Company.
3:00	Discussion.
3:30	Paper. Course Contents Recommended at National Conference at Rainy Lake and a Recommended Series of

Surveying Courses which May be Desirable in the Civil Engineering Curriculum, W. H. Rayner, University of Illinois.

4:00 Discussion, H. B. Aiken, University of Tennessee.
4:30 Adjourn.
5:30– 6:30 Dinner.
7:00–10:00 Informal inspection trip under the direction of Col. D. A. Davidson, District Engineer, Louisville District U. S. Engineer Office. Board U. S. Cayuga for moonlight trip on the Ohio River passing through one of the Ohio River Locks. Short talk on "Canalization of the Ohio River" at the Lock.
10:00 Return to Otter Creek.

Wednesday, September 7

7:00– 7:45 A.M. Breakfast.
8:00–11:30 Third Formal Session. Earl Church, University of Syracuse, presiding.
8:00 Paper. Teaching the Elements of Photogrammetry, H. O. Sharp, Rensselaer Polytechnic Institute.
8:45 Discussion.
9:00 Paper. Photogrammetric Mapping Under T.V.A. A. O. Anderson, Assistant Photogrammetrist, Tennessee Valley Authority.
9:45 Discussion.
10:00 Paper. Photogrammetric Methods and Equipment, Capt. Rummagi's Corps of Engineers, U. S. Army, Wright Field, Dayton, Ohio.
10:45 Discussion.
11:00 Adjourn.
12:00– 1:00 P.M. Luncheon
1:30– 4:30 Inspection trip to Fort Knox, the site of the U. S. Gold Depository, and station of the Mechanized Cavalry. (7 miles.)
Inspection of aerial photographic equipment and photogrammetric equipment, including planes, cameras, and photogrammetric instruments, under direction of Capt. Rummagi, Corps of Engineers, U. S. Army.
Demonstration by the First Mechanized Cavalry.
5:30– 6:30 Dinner at Otter Creek.
7:30– 9:30 Informal session, possibly campfire. Master of Ceremonies to be announced. ....
Entertainment to be arranged. An evening of fun.

Thursday, September 8

7:00– 7:45 A.M. Breakfast.
8:00–11:45 Fourth and final Formal Session. J. S. Dodds, Iowa State College, presiding.
8:00 Announcements:
National Surveying Conference for 1940.
Other Regional Surveying Conferences.
T.V.A. Inspection Trip.
Report of committees which may have been appointed.

8:30	Paper. The Effect of Licensing Laws on Surveying and Mapping Instruction, Paul P. Rice, Lafayette College.
9:00	Discussion.
9:30	Paper. Federal and State Mapping Programs, Colonel William Bowie, Chairman Surveying and Mapping Division Am. Soc. C. E.
10:00	Discussion.
10:30	Paper. W.P.A. Control Surveys, M. Y. Poling, Works Progress Administration, Washington, D. C.
11:00	Discussion.
11:30	Adjourn.
12:00– 1:00 P.M.	Luncheon, Official adjournment of Kentucky Conference.
1:00– ————	Pack and leave for home or T.V.A. Inspection Trip.

S. P. E. E. Civil Engineering Division Committee 8—Surveying and Geodesy Kentucky Conference Special Committee

Program Section

J. S. Dodds, Iowa State College.
M. W. Todd, Purdue University.
W. H. Rayner, University of Illinois.
E. F. Coddington, Ohio State University.
H. B. Aiken, University of Tennessee.

Local Arrangements Section

W. B. Wendt, University of Louisville.
W. R. McIntosh, University of Louisville.
J. M. Houchens, University of Louisville.
D. V. Terrell, University of Kentucky.
Col. D. A. Davidson, U. S. District Engineer.
James B. Wilson, City Engineer, Louisville, Ky.
Woolsey M. Caye, Chief Engr. Commissioners of Sewerage, Louisville, Ky.
G. H. Harding, Chairman, University of Louisville.

Address all communications to G. H. Harding, University of Louisville.

SECTIONS AND BRANCHES

The **Illinois-Indiana Section** held its fourth annual meeting at Rose Polytechnic Institute, Terre Haute, Indiana, on Saturday, May 7, 1938.

MORNING SESSION—10:00–11:45 A.M. President O. L. Stock, presiding.

Welcome, Dr. D. B. Prentice, President, Rose Polytechnic Institute.

Address, "Teaching Fundamentals," John Mills, Director of Publication, Bell Telephone Laboratories, Incorporated, New York City.

Business Session and Election of Officers.

LUNCHEON—12:00 noon.

AFTERNOON SESSION—1:00–3:00 P.M.

Group Conferences as follows:

Chemical Engineering, R. E. Rich, University of Notre Dame, Chairman.

What Constitutes a Desirable Chemical Engineering Laboratory, Robert C. Kintner, Armour.

The Teaching of Thermodynamics to Chemical Engineers, Edward W. Comings, Illinois.

Organic Chemical Technology, G. F. Hennion, Notre Dame.

Civil Engineering, W. L. Shilts, Notre Dame, Chairman.

Specialization in a Four Year Undergraduate Course vs. General Fundamental Training, W. C. Huntington, Illinois.

Laboratory Work in Hydraulics and Sanitary Engineering, H. A. Vagtborg, Armour.

Teaching Highway Engineering, Ben H. Petty, Purdue.

Problems and Laboratory Work in Highway Engineering, C. C. Wiley, Illinois.

Economics, J. F. Lee, Lewis Institute, Chairman.

Accounting for Engineering Students, D. B. Prentice, Rose.

Management for Engineers, Alexander Davidson Bailey, Commonwealth Edison Company, Chicago.

Economics in the Engineering Curriculum, Everitt E. King, Illinois.

Electrical Engineering, M. A. Faucett, Illinois, Chairman.

The Value of Laboratory Reports, A. W. Sear, Armour.

Comprehensive Examinations, Limiting Student Enrollment, D. T. Canfield, Purdue.

Selection of Non-Technical Electives, A. R. Knight, Illinois.

Engineering Drawing, W. G. Smith, Northwestern, Chairman.
Theme: Making our Training Count.
Improve our Raw Material, F. M. Porter, Illinois.
To What Extent Should Partial Layouts be Employed in Teaching Drafting? W. H. Seegrist, Armour.
Can Engineering Drafting and Descriptive Geometry be Made Subjects of University Calibre? C. E. Hammett, Armour.
Advance Graphics, J. N. Arnold, Illinois.
English and Modern Languages, John T. Fotos, Purdue, Chairman.
The Purdue Plan for Teaching German to Chemical Engineers, J. L. Cattell, Purdue.
English in Engineering Colleges, J. L. Bray, Purdue.
Discussion, F. B. Seely, Illinois; R. B. Parks, Lewis.
Panel Discussion: The Benefits Derived by the Engineering Student from his Study of English and Modern Languages.
An Engineering Professor's Opinion, H. McCormack, Armour.
A Modern Language Professor's Opinion, Fred Genschmer, Rose.
An English Professor's Opinion, Walter Hendricks, Armour.
The Work of the Committee on Standards in English at Purdue University, J. H. McKee, Purdue.
Mathematics, F. Robert Marks, Lewis, Chairman.
Mathematics and Industry, John Bartky, District Superintendent of Schools, Chicago.
Mathematical Charts and Models, W. A. Spencer, Armour.
Mechanics, C. O. Harris, Armour, Chairman.
The Relation of the Work in Mechanics to That of the Professional Departments.
The Civil Engineer's Viewpoint, S. M. Spears, Armour.
The Chemical Engineer's Viewpoint, C. L. Lovell, Purdue.
The Electrical Engineer's Viewpoint, C. C. Knipmeyer, Rose.
The Mechanical Engineer's Viewpoint, E. L. Broghamer, Illinois.
Mechanical Engineering, G. W. Munro, Purdue, Chairman.
The Mechanical Engineering Curriculum, E. S. Ault, Purdue.
Discussion, W. A. Pearl, Armour.
The Teaching of Mechanical Engineering Subjects, E. G. Ryan, Illinois.
Discussion, C. Wischmeyer, Rose.
Shop Laboratories, W. A. Pearl, Armour, Chairman.
Welding Courses for Engineering Students, A. M. Candy, Hollup Corporation.
Discussion, J. Rising, Purdue.
Service Engineering Shop Courses, C. H. Casberg, Illinois.
Discussion, R. E. Wendt, Purdue.

Satisfying the Engineering Shop Laboratory Courses, R. W. Lindley, Purdue.
Discussion, C. J. Starr, Illinois.

The **Kentucky Section** of the Society held a meeting on April 30, 1938, in the lecture room of the Speed Scientific School, University of Louisville. There were twenty members and guests present. The meeting was called to order by President D. V. Terrell who presented a brief synopsis of the annual meeting of the Southeastern Section held at Clemson College on April 22 and 23, 1938.

The president appointed the following members of the nominating committee—Professors Bureau, Fenwick, McIntosh.

Professors Wendt and Jett were appointed to present resolutions concerning the death of Dean B. M. Brigman and to incorporate such resolutions in these minutes.

Professor G. H. Harding presented a paper on Correlation of Freshman Placement Tests with Scholastic Achievement. The paper is attached to these minutes.

In a discussion of Professor Harding's paper Mr. John M. Houchens pointed out that in a statistical study of graduates relative to their placement test averages, 82.7 per cent of those placed in the first quartile graduated; 60.5 per cent of those in the second quartile graduated; 49 per cent of those in the third and 20.3 per cent of those in the fourth quartile graduated. Also it was shown that of those who graduated the following percentage of each quartile required more than the allotted time to graduate:

First quartile	0
Second quartile	8.7
Third quartile	29.2
Fourth quartile	69.2

From these data it is observed that there is a very close connection between students' placement test scores and their performance leading to graduation.

D. M. Bennet spoke on Cultural Courses in an Engineering Curriculum. Dr. Bennet presented the following premises and conclusions: We try to educate men, not train them technically. An educated man should know everything about one thing and something about everything. In teaching everything about one thing, we create a narrow individual. When we teach something about everything, we create the survey course. These courses which must, of necessity, replace thorough-going engineering courses, lead in general to a dislike of the subject covered. Even an appreciation of a musical composition can be obtained only by

attending an orchestra rehearsal and by watching the development of the final product.

The preparation for culture should be based on the following items:

(1) Foundation of fact.
(2) Critical examination.
(3) Logical thinking.
(4) Exploration of the unknown.

These can be taught better by giving a thorough comprehensive course in any subject rather than by surveys which are superficial. Human nature makes the individual more hungry for those things left out of his diet than for those things which are fed to him in indigestible units.

The Nominating Committee recommended the following men as officers for the ensuing term: For President, Professor R. C. Ernst; for Vice-President, Professor C. C. Jett; for Secretary-Treasurer, Professor G. H. Harding. The nominees were elected unanimously.

C. C. JETT,
Secretary.

CORRELATION OF FRESHMEN PLACEMENT TESTS WITH SCHOLASTIC ACHIEVEMENT *

BY GEORGE H. HARDING, Assistant Professor Civil Engineering and Mathematics, University of Louisville

We engineering educators are engaged in producing a product. That product is our graduate. We, as engineers, would frown upon and reject, if it lay within our power, any material for use in commercial production which did not satisfy the specifications essential to the satisfactory performance of that material. Our incoming freshmen compose the material of which our product, the graduate, must be made. This material varies widely and much must be discarded as unfit for the purpose intended as is evidenced by the high rate of mortality at our engineering institutions during the first year. This does not mean that this material is worthless in any sense of the word, but rather that an attempt has been made to use a material for a purpose for which it is not suited. In other words we have a definite need for specifications for our human raw material.

There has been an attempt through the last decade to develop some test or tests by means of which such specifications might be written. These attempts have met with varying degrees of suc-

* Presented before the Kentucky Section, S. P. E. E., at the annual meeting, April 30, 1938.

cess dependent, for the most part, upon the patience and perseverance of those interested in finding a solution to this problem.

Placement tests of many kinds have been devised including a wide variety of subjects and involving both mental and manual dexterity. Some of these tests have shown definite results which justify the efforts made to perfect them. There is no doubt, that in the not too far distant future, methods of selection of individuals by some series of tests by persons trained in their usage, will enable educators to eliminate to a large degree, those who are not suited for a particular field of endeavor.

Some of us here at the Speed Scientific School were privileged several nights ago, to hear President Davis, of Stevens Institute of Technology, speak on a subject which involved the findings of himself and his colleagues on some such tests. The results of those tests, in his own institution and in the industrial organizations where they have been given, was most interesting. The point which Dr. Davis mentioned several times that no test is infallible, was well taken, *but* a series of these tests judged by competent and experienced persons was correctly indicative of ability for such a large per cent of the persons tested that they could not be ignored.

May I call your attention to the efforts of other individuals and institutions to solve this problem. In an article in a current issue of THE JOURNAL OF ENGINEERING EDUCATION by Dean Fred E. Ayer, of the College of Engineering of the University of Akron, on "Physics, Mathematics and Engineering," the following conclusion was reached as a result of studies extending from 1921 to 1931, inclusive. "Our conclusion is that the engineering students who cannot, or will not, pass mathematics and physics in their first semester, better transfer to some other department."

In the same issue of this publication under the subject of "An Analysis of Freshman Engineers" by the Assistant Registrar of the University of Texas, we find several conclusions reached from which, may I quote the following: "That Freshman Performance in the University has a definite relationship to the students performance in high school, and that the good high school student will tend to do well in the University.

"That students who take certain related combinations of subjects in high school, in general have a better scholastic record in the freshman year in the University than those students who have not had the same combination of high school subjects."

A great many educational institutions have for some years been giving placement examinations to their incoming freshman. What is being done with the results of these examinations? What use is being made of these results? In many instances, none. Certainly a definite effort should be made to prove them of value, or

not, as the case may be, and action be taken according to the findings.

The Speed Scientific School in 1930, introduced placement examinations for the entering freshman classes. These examinations included English Aptitude, English Training, Mathematics Aptitude, Mathematics Training, Chemistry Aptitude, and Physics Aptitude Tests. A psychological test has been given also, but not continuously during the period 1930 to present date.

With the permission of the late Dean Brigman in 1931, I began experimenting with the results of some of these tests. With small classes the results of the tests compared with corresponding quartiles in some of their freshman subjects was not conclusive. In some instances a ninety per cent accuracy of prediction was obtained, but this was off-set by other instances of much less accuracy so as to leave the net value questionable.

Very soon the conclusion was reached that the English Aptitude test we were using apparently had no real significance in determining the general fitness of the student to master mathematics and the science courses of chemistry and physics. So for the time being these were eliminated from the computations used although they are still given and records kept.

Due to the fact that most of these placement tests have widely varying possible scores, for the purpose of this experiment, all scores were reduced to per cents of maximum score, and the combined percentages obtained in this manner from four of the tests given including Mathematics Aptitude, Mathematics Training, Chemistry Aptitude and Physics Aptitude, were averaged. This composite average, for want of a better name, is labelled "Math-Science Averages."

A card index system was then built up, upon each card being the name of the student and in the upper left hand corner the index number representing his Math-Science Average. These cards are filed in descending order of this average and the file divided into quartiles by wooden spacers.

Pertinent information concerning high school grades, university grades, reasons for failing to graduate, graduation with honors in four years or in five years, and subsequent employment, are kept on these cards by means of a tab system. This permits of a visual comparison of these items by quartile over a period of years for the purpose of determining any correlation which may exist between this series of tests and scholastic achievement.

As has been stated before, variation in individual classes is marked in some instances, however a study of this file will bring out certain definite conclusions, when based on a large number of students over a period of years.

The conclusions reached are as follows:

1. Individuals having high four year averages in Speed Scientific classes, occur in the ratio 11—5—2 for the first three quartiles; showing a definite relationship over a period of years with the Math-Science rating.

2. Individuals having average four year averages are concentrated in the second and third quartiles, verifying the relationship shown in 1.

3. Individuals having low four year averages occur in the ratio 1—2—5 in the second, third and fourth quartiles.

4. Honors graduates with one exception, are all in the first quartile.

5. Students graduating in four years without honors, are distributed throughout the upper three quartiles.

6. Students requiring more than four years to graduate increase in descending order of quartile.

7. Students failing to graduate, due to scholastic reasons, are predominantly fourth quartile.

The above bears out the statement that a definite relationship exists between the Math-Science Average and scholastic achievement. The conclusions above are the results of eight consecutive years of tests, and it appears to be advisable to point out to students who place in the fourth quartile in future incoming classes, that the probability of their satisfactorily completing the required course in four years, is negligible. This is not to be construed as an attempt to deny any student the right to enter if he satisfies the entrance requirements, and realizing the odds against him, is still determined to attemp the course.

The **Michigan and Ohio Sections** held a joint meeting at the University of Toledo, April 30, 1938, *Chairman*—D. M. Palmer.

Address of Welcome—Dr. E. J. McCormick, Member of Board of Directors, University of Toledo.

Appointment of Nominating Committees.

Greetings from S. P. E. E.—Dr. S. B. Earle, President of the Society.

Address by E. G. DeCoriolis, Director of Research, Surface Combustion Co., Toledo. "General Fundamental Engineering Training for Student Engineers and the Industrialist's View Point of such Training."

General Discussion.

Business Meetings—Michigan Section; Ohio Section.

Chairman—R. H. Schoonover

What Is the Engineering College Doing For and To Its Students Who Have Trade-School Minds?—H. H. Higbie, University of Michigan.

Discussion: A. R. Alliason, Wayne University; John Younger, Ohio State University.

General Open Meeting.

Adjournment and Inspection of Building.

SADA A. HARBARGER,
Secretary, Ohio Section.

The seventh annual meeting of the **Missouri Section** of the S. P. E. E. took place at the University of Missouri at Columbia, Missouri, on April 1 and 2. In addition to the members of the Section there were several visitors from the University of Nebraska, Kansas, State College, and the University of Kansas. The total attendance was 112.

At the dinner on April 1 at the Daniel Boone Tavern President Middlebush, University of Missouri, addressed the Section on the subject "The University President Looks at the Engineering School." Dr. Middlebush stated that the first thing to strike a president's eye was the large outlay required for the College of Engineering as compared to other colleges. He also noted the extreme importance to society of having its engineers trained in rigorous accuracy, both as to numerical results and in the search for truth. It was suggested that while the old idea of an engineer as a man wearing boots and a khaki shirt is now outmoded, there still may be a need of further emphasis on the human side of engineering education. Dr. Middlebush recommended that if it can be done without sacrificing that rigorous accuracy which is of prime importance, but only if it can so be done, engineers be given more training in those things which will make them more at ease with other people, including an appreciation of beauty and an appreciation of the many possibilities of modifying their designs to attain it.

Following the dinner, group meetings were held in the Engineering Laboratories building of the University of Missouri, and in several cases these meetings were continued on Saturday morning.

The ladies were entertained after the dinner by the reading of several plays under the direction of Mrs. A. L. Hyde. On Saturday morning the ladies inspected Christian College and Stephens College.

The program meeting of the section was convened by Professor F. W. Bubb of Washington University on Saturday morning at 9:30. The first paper, by E. W. Carlton of the School of Mines of the University of Missouri on The Missouri Society of Professional Engineers and its Work aroused considerable interest and was discussed by R. A. Seaton, Kansas State College, and O. E. Edison, University of Nebraska, as well as by several members of the Missouri section. A. S. Langsdorf, Dean of Engineering at Washington University, presented a paper on E. C. P. D. Accrediting Procedures. In the ensuing discussion it was brought out that the E. C. P. D. made no attempt to specify or control the sequence or content of courses but attempted rather to judge performance standards. W. R. Chedsey, School of Mines and Metallurgy of the University of Missouri, gave the section a view of

Engineering Education in Missouri as a Newcomer Sees It. Among the interesting comments, was the observation that the Junior College, with all its concomitant problems, is distinctly a Western institution, an outgrowth probably of the relatively great distances between universities and the students desiring to attend them.

The business meeting was called to order by President Armsby at 11:30. The Committee on Nominations presented its report, nominating W. R. Chedsey for President, J. R. Lorah for Vice-President, and Eugene Stephens for Secretary. The report of the nominating committee was accepted and the candidates elected by acclamation.

T. J. Rodhouse, Chairman of the Committee on Resolutions, read the report of that committee. It was moved, seconded, and carried that the report be accepted in full, including the suggestion of the committee that invitations to attend our group meetings be extended further to include Oklahoma, Arkansas, Iowa State College and the University of Iowa, those colleges who are our immediate neighbors, located within the area of the South Central part of the "Louisiana Purchase."

Group Chairmen reported as follows:

Chemical Engineering: J. R. Lorah reported that the nine men in attendance discussed the place of specialized courses in Chemical Engineering and agreed that they were in general undesirable. Dr. F. H. Conrad was elected chairman for next year.

Civil Engineering: A. W. Brust reported that approximately twenty attended. The discussion was directed toward the place in the curriculum of specialized courses such as Statically Indeterminate Structures, Soil Mechanics, and the like. E. W. Carlton was elected chairman for 1938–1939.

Electrical Engineering: A. S. Langsdorf reported that about twenty attended. The main topic was the proper sequence of subjects in Electrical Engineering. C. M. Wallis was elected chairman for next year.

English: E. L. Johnson reported that the group discussed the setting of minimum requirements in English, and concluded that they should be set as high as possible. It was recommended that the group be made a permanent part of the Missouri Section.

Mathematics and Physics: Eugene Stephens reported that that group continued the Friday evening meeting on Saturday morning and that the following conclusions were arrived at:

1. Experiments show that all attempts at segregation on ability have failed so far. Inferior groups harm a teacher and discourage a student. Superior groups promote jealousies.

2. Applications should be brought in only to point the need of general theory.
3. Fundamental concepts should be thoroughly taught to give the student ability to think and to analyze rather than to imitate. Texts should be chosen with this in mind.
4. We find the secondary background of students too meager in fundamentals. Statistics show fewer and fewer students are taking mathematics in high school.
5. It is the conviction of this group that it is time for the entire group of Engineering educators to take serious account of the fact that they are cramping the efforts of the mathematics and physics departments to give a general scientific background and sub-stratum for all Engineering. This is occurring on three specific fronts:

    1. The demand for too many practical applications.
    2. The tendency to take out of engineering textbooks general fundamental ideas and replace them with particular, highly detailed concepts.
    3. The general tendency to keep adding too many things at the top and squeezing out fundamentals at the bottom.

The group requests that an invitation to attend these meetings be extended to Mathematics teachers and Physics teachers of the small colleges and junior colleges which supply students to the three schools composing the Missouri Section. Eugene Stephens was elected chairman for next year.

Mechanical Engineering: R. L. Scorah reported that the subject matter content of service courses required by the curriculum in mechanical engineering was discussed under four classifications, namely those given by other engineering departments and those given by departments not in the Engineering College, and in each case, those courses which are prerequisite to M. E. courses and those which are not. About 12 attended. R. O. Jackson was elected chairman for next year.

R. B. VAILE,
Secretary.

COLLEGE NOTES

Cornell University.—J. N. Goodier, who holds the degrees of Ph.D. from Cambridge University, England, and Sc.D. from the University of Michigan, has been named acting professor of mechanics in the Sibley School of Mechanical Engineering. Widely known for his research in elasticity, plasticity, and advanced dynamics, Dr. Goodier comes to Cornell from the Ontario Research Foundation, where he has been research fellow in applied mechanics since 1931.

He was born in Preston, England, in 1905, won a scholarship to Cambridge from the Preston Grammar School, and received his B.A. degree in 1927, passing first class examinations in mathematics and the mechanical sciences. He remained at the University for two years as a graduate student. While at Cambridge he won the Rex Moir Prize for general distinction in the mechanical sciences, the Ricardo Prize for thermodynamics, and the Winbolt thesis prize.

From 1929 to 1931, he was a Commonwealth Fund fellow at the University of Michigan, assisting Professor S. Timoshenko in the preparation of his book, "The Theory of Elasticity," and doing original research. In 1931 he received doctorates from Cambridge and Michigan. He holds two patents on industrial viscometers and has published numerous articles in technical magazines.

The **University of Delaware** announces the appointment of Dr. Allan P. Colburn as Head of the Division of Chemical Engineering and the administrative separation of Chemistry and Chemical Engineering. To his colleagues in the Chemical Engineering profession, Dr. Colburn will be recalled as the first winner of the William H. Walker Award of the American Institute of Chemical Engineers, a productive research worker in the Experiment Station of E. I. duPont de Nemours & Company, and a prolific writer of valuable articles on the subject of Heat Transmission. Dr. Colburn will assume his new duties on May 1, 1938. Among his first duties will be the installation of a five-year curriculum in Chemical Engineering, and the completion of the new Chemical Engineering Laboratory. Dr. Albert S. Eastman, who formerly performed the double duty of Professor of Chemistry in the Arts and Science School and Head of the Division of Chemical Engineering in the School of Engineering, will continue his duties as Professor of Chemistry in the Arts and Science School.

Dr. D. U. Greenwald has been appointed to replace Mr. Arthur M. G. Moody in the Division of Mechanical Engineering. Mr. Moody is leaving the University to take charge of the research and development of the DeLaval Steam Turbine Company. Dr. Greenwald comes to the University with a Ph.D. in Psychology and a Bachelor's degree in Mechanical Engineering. With this valuable and unique training, he is well fitted to teach courses in Industrial Management, and especially in Industrial Psychology.

University of Detroit.—An evening school in freshman and sophomore courses only will be established in the College of Engineering in September, 1938. The purpose of this evening school is to accommodate high school graduates who are qualified for the study of engineering but who are not financially able to attend day school. After completing the freshman and sophomore courses in the evening school these students may become co-operative day students and solve their financial problem by part-time employment under the co-operative plan.

This evening school will differ from the conventional night school. No great variety of courses will be offered; it will be assumed that the students are preparing themselves for an engineering degree and that they will enroll for the regular curriculum. The work of the regular freshman and sophomore years will be spread over four years of the evening school so that students may pursue these courses while engaged in daytime employment in Detroit industries. The first semester courses of the day school will be taught in the first year of the evening school, second semester courses of the day school will be taught in the second year of the evening school, etc. Only the courses of the first day school semester will be offered in the first year of the evening school.

The standards of admission and promotion and the quality and quantity of the work required, will be exactly the same as in the day school.

The evening school courses will be taught by the regular faculty of the College of Engineering; the regular faculty may be enlarged as need arises to take care of the evening school teaching but no special, part-time teachers will be engaged for evening courses.

Massachusetts Institute of Technology.—The Executive Committee has authorized changes affecting the Institute's work in Electrochemistry and Mining. Because of the expanding opportunities for the application of the methods of electrometallurgy and electrochemistry to both science and industry the Department of Metallurgy has been asked to provide training for all its graduates

in electrothermics and electrotytics. The Department of Chemical Engineering will undertake that part of the instruction and research which treats of processes and substances other than metals. With these changes in operation, the present course in Electrochemical Engineering will be discontinued after June, 1940.

Because of the need in the mining industry for men trained in physics, chemistry, geology, and economics, it appears that under present conditions the best use of Technology's facilities can be made in the fields of discovery, recovery, and the processing of metals. The Executive Committee has accordingly voted also to discontinue the special curricula in Mining Engineering in June, 1940. The Department of Geology will extend its work on Mineral Resources and the Department of Metallurgy will pay special attention to the recovery of metal from ores.

Research work in Structural Petrology is at present being conducted by Professor H. W. Fairbairn of the Department of Geology. Although investigations of this character are carried on at relatively few schools, their value is apparent in many branches of the science.

Providing a more efficient means of answering the mechanical engineering problems of turbine design has required the recent services of an astrophysicist, and a chemical and mechanical engineer. The result of their efforts is a blueprint chart, thirty inches wide and fifteen feet long, cross hatched with a maze of lines and beautifully drawn curves. This, an enthaipy-entropy chart based on the "Thermodynamic Properties of Steam" published last year by Professors J. H. Keenan and F. G. Keyes, mechanical engineer and chemist, respectively of the Institute, was accomplished under their supervision by Dr. Carol Anger Rieke. Pressures are plotted against temperatures on the chart for use in the design of large low-pressure turbines. By incorporating the data from the Keenan-Keyes steam tables this chart avoids the necessity of interpolation to determine the desired figure. After the data from the tables had been plotted, Dr. Rieke accomplished the delicate task of laying off the long sweeping curves with the aid of naval draftsman's splines.

The new Structural Analysis Laboratory which was opened this year in the Department of Civil and Sanitary Engineering has aims which are both educational and scientific. By providing facilities for research by staff members as well as by students, progress along both lines has been made.

The work which has been carried out so far may be divided into two general fields; investigation into structural action so that current structural theories may be checked and in some cases modified; and the study of methods of model analysis whereby long

mathematical analyses can be avoided through the interpretation of the action of structural models.

About half of the work is done with metal models, steel, duralumin, and brass being commonly used. For other approaches, plastics are used; celluloid and bakelite are especially convenient.

University of Michigan announces special courses to be offered in the Summer Session, June 27 to August 19, which are designed to meet the needs of advanced students, research engineers, and teachers in the technical schools and colleges who may wish to qualify for higher degrees either at this University or elsewhere. There are wide ranges of courses offered in Chemical Engineering, Civil Engineering, Electrical Engineering, Engineering Mechanics, as well as Mathematics, Physics and related subjects.

As special features we wish to call attention to Visiting Professors: S. Timoshenko, Stanford University; Th. von Karman, California Institute of Technology, and L. S. Jacobsen, Stanford University.

For information concerning the courses, expenses, or the requirements for graduate credit, correspondence should be addressed to Professor Louis M. Eich, Secretary of the Summer Session, University of Michigan, Ann Arbor, Michigan, by whom it will be referred to such officer of the University as may be concerned.

NEW MEMBERS

BARBER, RAYMOND J., Dean, School of Mines, University of Alaska, College, Alaska. W. E. Duckering, F. L. Bishop.

BARCLAY, LELAND, Assistant Professor of Civil Engineering, University of Texas, Austin, Texas. S. P. Finch, H. E. Degler.

BARRETT, EDWARD C., Assistant Professor of Chemical Engineering, West Virginia University, Morgantown, W. Va. G. P. Boomsliter, W. W. Hodge.

BAUER, GEORGE C., Professor of Chemistry and Chemical Engineering, A. & M. College of Texas, College Station, Texas. N. F. Rode, M. C. Hughes.

BEER, ROBERT G., Assistant Professor of Civil Engineering, Polytechnic Institute of Brooklyn, Brooklyn, N. Y. E. J. Streubel, E. J. Squire.

BELKNAP, J. HARRISON, Manager, Technical Employment and Training, Westinghouse E. & M. Co., East Pittsburgh, Pa. E. B. Roberts, F. L. Bishop.

BERKEL, HOWARD J., Instructor in Engineering Drawing, Iowa State College, Ames, Iowa. H. J. Gilkey, L. O. Stewart.

COLBURN, ALLAN P., Professor and Head, Dept. Chemical Engineering, University of Delaware, Newark, Del. R. L. Spencer, E. M. Schoenborn.

EDER, CHARLES A., Instructor in Civil Engineering, Pennsylvania State College, State College, Pa. L. W. Whitehead, L. A. Doggett.

GAFFORD, B. NEWMAN, Assistant Professor of Electrical Engineering, University of Texas, Austin, Texas. J. W. Ramsay, H. E. Degler.

JOHNSTONE, B. KENNETH, Professor and Head, Dept. of Architecture, The Pennsylvania State College, State College, Pa. F. L. Bishop, Nell McKenry.

KEMMER, LLOYD H., Instructor in Civil Engineering, Purdue University, Lafayette, Ind. M. W. Todd, G. P. Springer.

KETCHUM, MILO S., Assistant Professor of Structural Engineering, Case School of Applied Science, Cleveland, Ohio. L. W. Miller, T. M. Focke.

KOZACKA, JOSEPH S., Associate Professor of Mechanical Engineering, Lewis Institute, Chicago, Ill. C. A. Anderson, R. B. Parks.

MANEY, G. A., Professor of Structural Engineering, Administrative Chairman, Northwestern University, Evanston, Ill. Re-instatement.

MCELROY, DENNIS L., Professor of Mining Engineering, Virginia Polytechnic Institute, Blacksburg, Va. G. P. Boomsliter, C. E. Lawall.

MCFARLAND, JAMES D., Assistant Professor of Drawing, University of Texas, Austin, Texas. W. H. McNeill, H. E. Degler.

MOHN, PAUL E., Assistant Professor of Mechanical Engineering, University of Illinois, Urbana, Ill. O. A. Leutwiler, J. C. Reed.

MORGAN, S. S., Professor of English, A. & M. College of Texas, College Station, Texas. N. F. Rode, M. C. Hughes.

PETERS, ARTHUR S., Instructor in Mathematics, New York University, New York City. S. K. Barrett, L. A. DeRonde.

POWER, HARRY H., Professor of Petroleum Engineering, University of Texas, Austin, Texas. J. W. Ramsay, H. E. Degler.

REED, MYRIL B., Assistant Professor of Electrical Engineering, University of Texas, Austin, Texas. H. E. Degler, J. W. Ramsay.

SCHWIEGER, ALBERT J., Professor and Head, Dept. Economics, Government and Business, Worcester Polytechnic Institute, Worcester, Mass. A. S. Knowles, A. W. French.

STEVENS, DON S., Instructor in Engineering Drawing, Iowa State College, Ames, Iowa. H. J. Gilkey, O. A. Olson.

VITTUCCI, ROCCO V., Instructor in Mechanical Engineering, University of Texas, Austin, Texas. H. E. Degler, M. L. Begeman.

358 new members this year.

The T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE DIVISION OF ENGINEERING DRAWING

FRED W. SLANTZ, EDITOR

A METHOD OF TEACHING SIZE DESCRIPTION

Few, if any, topics in the study of Engineering Drawing have undergone more extensive revision than the teaching of size specification and description. Instead of the aggregation of rules and methods used in the past, we approach this vital subject through the medium of rational theory and analysis, as presented in the many excellent texts now extant. The student, at the beginning, is taught to segregate the primary elements of an object, to differentiate between size and location dimensions, and in general to treat the problem in a logical manner.

In considering the study of size description, one fact should not be overlooked—that size description is much more relative than absolute. The significance of any dimension should be gaged by its relation to other dimensions on contiguous parts of the device or mechanism under consideration. A student tends to neglect this point, particularly if engaged in drawing isolated parts or models. If, however, the student begins the study of this subject by delineating the component parts of a device—be it ever so simple—he rapidly becomes aware of that coherence and unity so necessary in work in size description. In detailing a bearing bushing, for example, he considers the outer diameter as related to the hole in which it fits, the inner diameter as related to the shaft which turns in the bushing, and the length as it affects any parts that may be placed on the shaft to provide axial constraint.

This approach inevitably involves some study, at least, of limit dimensioning. One may justifiably ask, however, will not the complexity of the American Standards Association specifications for fits and tolerances, necessary as it is for the advanced student and practicing engineer, be wasteful of the time and enthusiasm of the beginner? The instructor can retain the pedagogical values inherent in limit dimension, however, by substituting a simple system of his own—comprising, for example, three types of fits—force, snug and free—with empirical allowances and tolerances, uniform for the entire range of sizes. He can then explain that the plan as used is purely illustrative, and that in actual practice an industry will either use the American Standards Association specification, or, as is still often the case, use a system adapted to its particular needs.

This mode of teaching size description in courses in Engineering Drawing is only one of doubtless many methods used by instructors in this field. Further discussion of this topic might be of interest to our division, conducted through the medium of this page, or at the usual meetings.

HERMAN C. HESSE,
Associate Professor of Engineering Drawing,
Department of Engineering,
University of Virginia.

THE FUNCTION OF THE ENGINEERING COLLEGE

By S. B. EARLE, President of the Society

In the engineering field there are needed not only the professional engineer for planning and directing but also technicians skilled in developing details of plans and artisans who have developed manual dexterity and experience in carrying out plans. Artisans usually receive their training in the trade school or technical high school, or in industry; the technician in the technical institute, while the professional engineer is usually trained in one of the many professional schools of engineering.

Rarely does the artisan have the necessary training to qualify him for entrance to an engineering college. Because of the lack of trade schools and technical institutes, especially in many sections of our country, some educators claim that it is the duty of the college to provide such training. Is it not rather the duty of the colleges to aid in fostering sentiment for the establishment of such schools in our larger cities and industrial centers? If such institutions were provided at proper locations the colleges might be relieved of the burden of handling many who cannot graduate.

There are many who enter the professional schools without sufficient training or ability, particularly in mathematics and English, to enable them to pursue their college course to completion. Others are not interested enough to apply themselves. There are only a limited number who have the necessary qualifications, training and persistence to complete the courses prescribed for a Bachelor's degree and who, by experience and continued study, finally qualify as a professional engineer. The college may be considered a place for testing as well as a place for training.

Since there are so many who drop out before graduation, some educators think the college has a real responsibility to these men and should offer courses particularly adapted to them. Since the student in the first two years has the regular courses in mathematics, physics, chemistry, history, drawing and shop, and in many cases an elementary course in economics, which courses are all valuable even to the technician, I feel the college has fulfilled its obligation to these men. It is true that the student may not have passed all the courses, often failing in mathematics or physics, or both. He still has received some benefit from these studies and if he has done a good job in the more practical courses he may

drop out with some assurance that the training he has received will be of considerable benefit to him if he enters industry.

The college does have a responsibility in making a study of the students, particularly in the first year and continued during the second in order that those not qualified may be discouraged from entering the third and fourth year. Some have found the comprehensive examination at the end of the second year useful as a means of carrying this out. It is usually found however that the ability to master mathematics and physics is a very good criterion that may be used with considerable accuracy in determining those who will finally graduate in engineering.

In order to preserve the status of the professional engineer we must maintain a high standard in our engineering colleges which will be much easier if we do not attempt to carry on two types of training at the same time and place. It is the duty of the college not to turn out engineers, but rather to provide proper related training which will enable the graduate later to qualify as a professional engineer.

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G-E *Campus News*

FOR OUTSTANDING ACHIEVEMENT

EACH year General Electric honors those employees who have done outstanding work in their fields as provided in the Charles A. Coffin Foundation. This year 40 men were chosen—15 of them college graduates:

Adelbert Alexay, Polytechnic Institute of Budapest, '11; *Alexander Babillis, Rose Polytechnic Institute, '28; *T. M. Berry, Kansas State College, '27; Michael Broverman, Tri-State College, '22; F. E. Carlson, University of Michigan, '25; *S. B. Crary, Michigan State College, '27; R. E. Farnham, Case School of Applied Science, '17; J. W. Gilchrest, Cooper Union, '08; *A. H. Lauder, University of Wyoming, '22; *Domenico Martignone, Central Technical College of London, '01; *F. N. Neal, University of Utah, '31; *D. R. Shoults, University of Idaho, '25; F. C. Smith, Drexel Institute, '06; *L. A. Umansky, Polytechnical Institute of Petrograd, '15; R. E. Worstell, Purdue University, '25.

If any one generalization could be made to cover the qualifications for this award, it would probably hinge upon the extent to which an employee took advantage of his opportunities, beyond the ordinary routine of his work to achieve an outstandingly worth-while result.

Former G-E Test man

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AFTER three years of photographing natural lightning striking the Empire State building in New York City, it was determined that many lightning strokes which appear to crash from the clouds to the ground actually are met part way by a small flash, originating from the earth, which guides the stroke to its destination.

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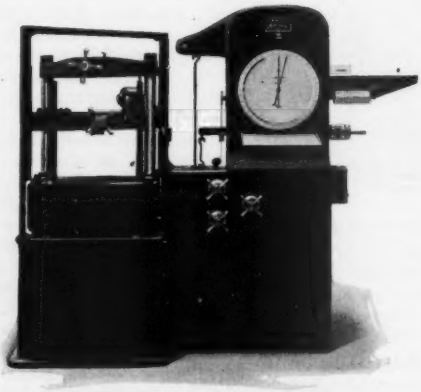

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ccredited Undergraduate Engineering Curricula in the United States

As Approved by

Engineers' Council for Professional Development

October 1, 1937

I. Engineers' Council for Professional Development: Organization and Accrediting Program.

II. List of Accredited Undergraduate Engineering Curricula.

III. Committee Personnel

Supplement to

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LIST OF ACCREDITED UNDERGRADUATE ENGINEERING CURRICULA

I. Introduction

(1) *Organization and Objectives*

The Engineers' Council for Professional Development has as its expressed objective the enhancement of the status of the engineering profession. To this end the Council has inaugurated a program dealing with the selection, guidance, training and recognition of the members of the profession. This program is being carried out under the direction of four operating committees. One of these, the Committee on Engineering Schools, is expected, as part of its broad purpose of assisting in the improvement of the status of engineering education, "to formulate criteria for colleges of engineering, which will insure to their graduates a sound educational background for practising the engineering profession."

One very important aspect of the activities of this committee is the procedure for accrediting engineering curricula. This phase of its program is intended to offer a single accrediting for the duplicated and uncoordinated procedures that have been used in the past. E. C. P. D., representing the American Society of Civil Engineers; the American Institute of Mining and Metallurgical Engineers; the American Society of Mechanical Engineers; the American Institute of Electrical Engineers; the American Institute of Chemical Engineers; the Society for the Promotion of Engineering Education; and the National Council of State Boards of Engineering Examiners is in a position to accredit engineering curricula under properly inclusive auspices.

E. C. P. D. is merely authorized by its constituent organizations to publish a list of accredited engineering curricula for use as desired by those agencies which require such a list. It has no authority to impose any restrictions or standardizations upon engineering colleges nor does it desire to do so. On the contrary, it aims to preserve the independence of action of individual institutions and to promote the general advancement of engineering education thereby.

Consideration of curricula with a view toward accrediting is done at the invitation of the institution.

(2) *Basis for Accrediting Engineering Colleges*

The following statement, proposed by the Committee on Engineering Schools and approved by the Council and by the constituent member organizations, embodies the principles in accordance with which accrediting is conducted.

I. Purpose of accrediting shall be to identify those institutions which offer professional curricula in engineering worthy of recognition as such.

II. Accrediting shall apply only to those curricula which lead to degrees.

III. Both undergraduate and graduate curricula shall be accredited. (Accrediting program at present embraces undergraduate curricula only).

IV. Curricula in each institution shall be accredited individually. For this purpose, the E. C. P. D. will recognize the six major curricula: chemical, civil, electrical, mechanical, metallurgical, and mining engineering—represented in its own organization, and such other curricula as are warranted by the educational and industrial conditions pertaining to them.

V. Curricula shall be accredited on the basis of both qualitative and quantitative criteria.

VI. Qualitative criteria shall be evaluated through visits of inspection by a committee or committees of qualified individuals representing the E. C. P. D.

VII. Quantitative criteria shall be evaluated through data secured from catalogs and other publications, and from questionnaires.

VIII. Qualitative criteria shall include the following:

(1) Qualifications, experience, intellectual interests, attainments, and professional productivity of members of the faculty.

(2) Standards and quality of instruction:

(*a*) In the engineering departments.

(*b*) In the scientific and other cooperating departments in which engineering students receive instruction.

(3) Scholastic work of students.

(4) Records of graduates both in graduate study and in practice.

(5) Attitude and policy of administration toward its engineering division and toward teaching, research, and scholarly production.

IX. Quantitative criteria shall include the following:

(1) Auspices, control and organization of the institution and of the engineering division.

(2) Curricula offered and degrees conferred.
(3) Age of the institution and of the individual curricula.
(4) Basis of and requirements for admission of students.
(5) Number of students enrolled:
    (*a*) In the engineering college or division as a whole.
    (*b*) In the individual curricula.
(6) Graduation requirements.
(7) Teaching staff and teaching loads.
(8) Physical facilities. The educational plant devoted to engineering education.
(9) Finances: investments, expenditures, sources of income.

Information supplied by means of the questionnaire, or otherwise, is for the confidential use of the E. C. P. D. and its agents and will not be disclosed without the specific written authorization of the institution concerned.

(3) *Accrediting Procedure*

An institution desiring accrediting of any or all of its undergraduate curricula which lead to a degree in engineering may communicate directly with the E. C. P. D. Committee on Engineering Schools. Arrangements will then be made for securing information by questionnaire and for an inspection of the educational facilities of the institution by a regional subcommittee.

Each committee of inspection is selected from the membership of the regional committee operating in the area in which the institution is located on the basis of the curricula to be considered. The visiting committee reports its findings to the regional committee, which after consideration of all available information submits to the Committee on Engineering Schools a set of tentative recommendations. Final decision as to accrediting rests with the Engineers' Council for Professional Development which passes on the recommendations made to it by the Committee on Engineering Schools.

Recommendations as to curricula in Chemical Engineering are transmitted to the Committee on Engineering Schools by the Committee on Chemical Engineering Education of the American Institute of Chemical Engineers. All visits of inspection of curricula not previously accredited by the A. I. Ch. E. are made concurrently with the general inspections of other curricula and the committees function as a single unit in each region. Curricula in Chemical Engineering previously approved by the American Institute of Chemical Engineers have been accredited by E. C. P. D. upon the recommendation of the Committee on Engineering Schools.

(4) *Scope of Accredited List*

This list includes only such undergraduate engineering curricula as have been judged by E. C. P. D. to be worthy of accrediting. It does not include certain specialized curricula submitted for consideration, which, though apparently outstanding in restricted fields, are not closely related to engineering as it is interpreted by E. C. P. D.

In some cases accrediting has been made provisional for a limited period (from one to three years), with reappraisal stipulated at the end of the period. The provisional nature of the accrediting is based upon conditions which E. C. P. D. has not found to be entirely satisfactory, but which may be quickly improved, or conditions which are now satisfactory but whose future appears precarious. Such conditions include the following: uncertainty as to financial status; need for minor additions to staff or equipment; curriculum new or in state of transition; uncertainty due to nature of administrative organization; unusual dependence upon strength of a single individual. In every case where provisional accrediting has been granted, the institution has indicated that an effort will be made to remedy the unsatisfactory condition within the stipulated period of provisional accrediting. The fact that accrediting may thus be provisional is, in each case, a confidential matter with E. C. P. D.

E. C. P. D. has yet under consideration curricula at five institutions which applied for accrediting with the request that the visits of inspection be made in 1937–38.

The present list, dating from October 1, 1937, will again be subject to revision in the fall of 1938. It replaces the first partial list which was released for publication in October of 1936.

(5) *Provision for Reinspection and Review*

The list of curricula which have been accredited by E. C. P. D. is to be revised annually. Through its Committee on Engineering Schools E. C. P. D. will keep currently informed relative to significant changes in curricula, staff, facilities, organization, enrollment, et cetera in institutions where curricula have been accredited, and will arrange to have certain institutions revisited each year. The personnel of the accrediting committees for the coming year will remain nearly unchanged, as will also the accrediting procedure.

Requests for further information relative to E. C. P. D. and the accrediting program may be addressed to A. B. Parsons, Secretary, Engineers' Council for Professional Development, 29 West 39th Street, New York, N. Y.

II. List of Accredited Undergraduate Engineering Curricula

(As of October 1, 1937, and subject to continual revision)

(*A*) *Arranged by Institutions*

University of Alabama
- Aeronautical Engineering
- Civil Engineering
- Electrical Engineering
- Industrial Engineering
- Mechanical Engineering
- Mining Engineering

University of Arizona
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering
- Mining Engineering

University of Arkansas
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

Armour Institute of Technology
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

Brown University
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

Bucknell University
- Civil Engineering
- Electrical Engineering

University of California
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering
- Metallurgical Engineering (Metallurgy)
- Mining Engineering
- Petroleum Engineering

California Institute of Technology
- Aeronautical Engineering (Six year course)
- Chemical Engineering (Five year course)
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

Carnegie Institute of Technology
- Chemical Engineering
- Civil Engineering (*a*)
- Electrical Engineering (*a*)
- Industrial (Management) Engineering (*a*)
- Mechanical Engineering (*a*)
- Metallurgical Engineering (*a*)

Case School of Applied Science
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering
- Metallurgical Engineering

University of Cincinnati
- Aeronautical Engineering
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

The Citadel
- Civil Engineering

Clarkson College of Technology
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

Clemson Agricultural College
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

College of the City of New York
- Civil Engineering (*a*)
- Electrical Engineering (*a*)
- Mechanical Engineering (*a*)

University of Colorado
- Architectural Engineering
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

Colorado School of Mines
- Geological Engineering
- Metallurgical Engineering
- Mining Engineering
- Petroleum Engineering

Columbia University
- Chemical Engineering (*b*)
- Civil Engineering (*b*)
- Electrical Engineering (*b*)
- Industrial Engineering (*b*)
- Mechanical Engineering (*b*)
- Metallurgical Engineering (*b*)
- Mining Engineering (*b*)

Cooper Union Institute of Technology
- Civil Engineering (*c*)
- Electrical Engineering (*c*)
- Mechanical Engineering (*c*)

Cornell University
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Industrial (Administrative) Engineering
- Mechanical Engineering

Dartmouth College
- Civil Engineering

University of Delaware
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

University of Detroit
- Aeronautical Engineering
- Architectural Engineering
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

Drexel Institute
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

Duke University
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

University of Florida
- Civil Engineering
- Electrical Engineering
- Industrial Engineering
- Mechanical Engineering

Georgia School of Technology
- Aeronautical Engineering
- Civil Engineering (*d*)
- Electrical Engineering (*d*)
- Mechanical Engineering (*d*)

Harvard University
- Civil Engineering (*e*)
- Communication Engineering (*e*)
- Electrical Engineering (*e*)
- Industrial Engineering (Engineering and Business Administration) (*e*)
- Mechanical Engineering (*e*)
- Metallurgical Engineering (Physical Metallurgy) (*e*)
- Sanitary Engineering (*e*)

Howard University
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

University of Idaho
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

University of Illinois
- Architectural Engineering
- Ceramic Engineering (Technical Option)
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- General Engineering (*f*)
- Mechanical Engineering

Metallurgical Engineering
Mining Engineering

Iowa State College
Agricultural Engineering (*g*)
Architectural Engineering
Chemical Engineering
Civil Engineering
Electrical Engineering
General Engineering (*f*)
Mechanical Engineering

State University of Iowa
Chemical Engineering
Civil Engineering
Electrical Engineering
Mechanical Engineering

Johns Hopkins University
Civil Engineering
Electrical Engineering
Mechanical Engineering

University of Kansas
Architectural Engineering
Civil Engineering
Electrical Engineering
Mechanical Engineering
Mining Engineering

Kansas State College
Agricultural Engineering (*g*)
Architectural Engineering
Civil Engineering
Electrical Engineering
Mechanical Engineering

University of Kentucky
Civil Engineering
Metallurgical Engineering
Mining Engineering

Lafayette College
Civil Engineering
Electrical Engineering
Industrial (Administrative) Engineering
Mechanical Engineering
Metallurgical Engineering
Mining Engineering

Lehigh University
Chemical Engineering
Civil Engineering
Electrical Engineering
Industrial Engineering
Mechanical Engineering
Metallurgical Engineering
Mining Engineering

Louisiana State University
Civil Engineering
Electrical Engineering
Mechanical Engineering
Petroleum Engineering

University of Louisville
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

University of Maine
- Civil Engineering
- Electrical Engineering
- General Engineering (*f*)
- Mechanical Engineering

Marquette University
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

University of Maryland
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

Massachusetts Institute of Technology
- Aeronautical Engineering
- Architectural Engineering
- Building Engineering and Construction
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Electrochemical Engineering
- General Engineering (*f*)
- Industrial Engineering (Business and Engineering Administration)
- Mechanical Engineering
- Metallurgical Engineering (Metallurgy)
- Mining Engineering
- Naval Architecture and Marine Engineering
- Public Health Engineering
- Sanitary Engineering

University of Michigan
- Aeronautical Engineering
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Engineering Mechanics
- Mechanical Engineering
- Metallurgical Engineering
- Naval Architecture and Marine Engineering
- Transportation Engineering

Michigan College of Mining and Technology
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering
- Metallurgical Engineering
- Mining Engineering

Michigan State College
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

University of Minnesota
- Aeronautical Engineering
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering
- Metallurgical Engineering
- Mining Engineering (Excluding Mining in Geology option)
- Petroleum Engineering

University of Missouri
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

Missouri School of Mines and Metallurgy
- Ceramic Engineering
- Civil Engineering
- Electrical Engineering
- Metallurgical Engineering
- Mining (Mine) Engineering (Excluding Mining Geology option)

Montana School of Mines
- Geological Engineering
- Metallurgical Engineering
- Mining Engineering

Montana State College
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

University of Nebraska
- Agricultural Engineering (*g*)
- Architectural Engineering
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

University of Nevada
- Electrical Engineering
- Mining Engineering

University of New Hampshire
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

University of New Mexico
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

New York University
- Aeronautical Engineering
- Chemical Engineering (*h*)
- Civil Engineering (*a*)
- Electrical Engineering (*a*)
- Mechanical Engineering (*a*)

New York State College of Ceramics (At Alfred University)
- Ceramic Engineering

Newark College of Engineering
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

North Carolina State College
- Ceramic Engineering
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

University of North Dakota
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering
- Mining Engineering

Norwich University
- Civil Engineering
- Electrical Engineering

Ohio State University
- Ceramic Engineering
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Industrial Engineering
- Mechanical Engineering
- Metallurgical Engineering
- Mining (Mine) Engineering

University of Oklahoma
- Architectural Engineering
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering
- Petroleum Engineering (Production Option)

Oklahoma A. & M. College
- Civil Engineering
- Electrical Engineering
- Industrial Engineering
- Mechanical Engineering

Oregon State College
- Civil Engineering (Excluding Business Option)
- Electrical Engineering (Excluding Business Option)
- Mechanical Engineering (Excluding Business Option)

University of Pennsylvania
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Mechanical Engineering

Pennsylvania State College
- Architectural Engineering
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Electrochemical Engineering
- Industrial Engineering
- Mechanical Engineering
- Sanitary Engineering

University of Pittsburgh
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Industrial Engineering

Mechanical Engineering
Metallurgical Engineering
Mining Engineering
Petroleum Engineering
Petroleum Refining

Polytechnic Institute of Brooklyn
Chemical Engineering (*h*)
Civil Engineering (*a*)
Electrical Engineering (*a*)
Mechanical Engineering (*a*)

Princeton University
Chemical Engineering
Civil Engineering
Electrical Engineering
Mechanical Engineering

Purdue University
Chemical Engineering
Civil Engineering
Electrical Engineering
Mechanical Engineering

Rensselaer Polytechnic Institute
Chemical Engineering
Civil Engineering
Electrical Engineering
Mechanical Engineering

Rhode Island State College
Civil Engineering
Electrical Engineering
Mechanical Engineering

Rice Institute
Civil Engineering
Electrical Engineering
Mechanical Engineering

University of Rochester
Mechanical Engineering

Rose Polytechnic Institute
Civil Engineering
Electrical Engineering
Mechanical Engineering

Rutgers University
Civil Engineering
Electrical Engineering
Mechanical Engineering
Sanitary Engineering

University of Santa Clara
Civil Engineering
Electrical Engineering
Mechanical Engineering

South Dakota State College
Civil Engineering
Electrical Engineering
Mechanical Engineering

South Dakota State School of Mines
Civil Engineering
Electrical Engineering

Metallurgical Engineering
Mining Engineering

University of Southern California
Petroleum Engineering

Stanford University
Civil Engineering
Electrical Engineering
Mechanical Engineering
Metallurgical Engineering
Mining Engineering
Petroleum Engineering

Stevens Institute of Technology
General Engineering (*f*)

Swarthmore College
Civil Engineering
Electrical Engineering
Mechanical Engineering

Syracuse University
Civil Engineering
Electrical Engineering
Industrial (Administrative) Engineering
Mechanical Engineering

University of Tennessee
Civil Engineering
Electrical Engineering
Mechanical Engineering

University of Texas
Civil Engineering
Electrical Engineering
Mechanical Engineering
Petroleum (Petroleum Production) Engineering

A. & M. College of Texas
Civil Engineering
Electrical Engineering
Mechanical Engineering
Petroleum Engineering

Texas Technological College
Civil Engineering
Electrical Engineering
Mechanical Engineering

Tufts College
Civil Engineering
Electrical Engineering
Mechanical Engineering

Tulane University of Louisiana
Civil Engineering
Electrical Engineering
Mechanical Engineering

Union College
Civil Engineering
Electrical Engineering

University of Utah
Civil Engineering
Electrical Engineering
Mechanical Engineering

Metallurgical Engineering
Mining Engineering

University of Vermont
Civil Engineering
Electrical Engineering
Mechanical Engineering

University of Virginia
Civil Engineering
Electrical Engineering
Mechanical Engineering

Virginia Military Institute
Civil Engineering
Electrical Engineering

Virginia Polytechnic Institute
Civil Engineering
Electrical Engineering
Industrial Engineering
Mechanical Engineering

Washington University
Architectural Engineering
Civil Engineering
Electrical Engineering
Industrial (Administrative) Engineering
Mechanical Engineering

University of Washington
Aeronautical Engineering
Ceramic Engineering
Chemical Engineering
Civil Engineering
Electrical Engineering
Mechanical Engineering
Metallurgical Engineering
Mining Engineering

State College of Washington
Civil Engineering
Electrical Engineering (Basic and Hydro-electric Options)
Mechanical Engineering (Basic Option)
Metallurgical Engineering
Mining Engineering (Excluding Mine Administration and Petroleum Engineering Option)

Webb Institute of Naval Architecture
Naval Architecture and Marine Engineering

West Virginia University
Civil Engineering
Electrical Engineering
Mechanical Engineering
Mining Engineering

University of Wisconsin
Chemical Engineering
Civil Engineering
Electrical Engineering
Mechanical Engineering
Metallurgical Engineering
Mining Engineering

Worcester Polytechnic Institute
Civil Engineering
Electrical Engineering
Mechanical Engineering
Yale University
Chemical Engineering
Civil Engineering
Electrical Engineering
Mechanical Engineering
Metallurgical Engineering (Metallurgy)

(*B*) *Arranged by Curricula*

Aeronautical Engineering
University of Alabama
California Institute of Technology (6 year course)
University of Cincinnati
University of Detroit
Georgia School of Technology
Massachusetts Institute of Technology
University of Michigan
University of Minnesota
New York University
University of Washington
Agricultural Engineering (*g*)
Iowa State College
Kansas State College
University of Nebraska
Architectural Engineering
University of Colorado
University of Detroit
University of Illinois
Iowa State College
University of Kansas
Kansas State College
Massachusetts Institute of Technology
University of Nebraska
University of Oklahoma
Pennsylvania State College
Washington University
Ceramic Engineering
University of Illinois (Technical Option)
Missouri School of Mines and Metallurgy
New York State College of Ceramics (at Alfred University)
North Carolina State College
Ohio State University
University of Washington
Chemical Engineering
Armour Institute of Technology
California Institute of Technology (Five year course)
Carnegie Institute of Technology
Case School of Applied Science
University of Cincinnati
Columbia University (*b*)
Cornell University

Drexel Institute
University of Illinois
Iowa State College
State University of Iowa
Lehigh University
University of Louisville
Massachusetts Institute of Technology
University of Michigan
University of Minnesota
New York University (*h*)
Ohio State University
University of Pennsylvania
Pennsylvania State College
University of Pittsburgh
Polytechnic Institute of Brooklyn (*h*)
Princeton University
Purdue University
Rensselaer Polytechnic Institute
University of Washington
University of Wisconsin
Yale University

Civil Engineering

University of Alabama
University of Arizona
University of Arkansas
Armour Institute of Technology
Brown University
Bucknell University
University of California
California Institute of Technology
Carnegie Institute of Technology (*a*)
Case School of Applied Science
University of Cincinnati
The Citadel
Clarkson College of Technology
Clemson Agricultural College
College of the City of New York (*a*)
University of Colorado
Columbia University (*b*)
Cooper Union Institute of Technology (*c*)
Cornell University
Dartmouth College
University of Delaware
University of Detroit
Drexel Institute
Duke University
University of Florida
Georgia School of Technology (*d*)
Harvard University (*e*)
Howard University
University of Idaho
University of Illinois
Iowa State College
State University of Iowa
Johns Hopkins University

University of Kansas
Kansas State College
University of Kentucky
Lafayette College
Lehigh University
Louisiana State University
University of Louisville
University of Maine
Marquette University
University of Maryland
Massachusetts Institute of Technology (Civil Engineering)
Massachusetts Institute of Technology (Building Engineering and Construction)
University of Michigan (Civil Engineering)
University of Michigan (Engineering Mechanics)
University of Michigan (Transportation Engineering)
Michigan College of Mining and Technology
Michigan State College
University of Minnesota
University of Missouri
Missouri School of Mines and Metallurgy
Montana State College
University of Nebraska
University of New Hampshire
University of New Mexico
New York University (*a*)
Newark College of Engineering
North Carolina State College
University of North Dakota
Norwich University
Ohio State University
University of Oklahoma
Oklahoma A. & M. College
Oregon State College (Excluding Business Option)
University of Pennsylvania
Pennsylvania State College
University of Pittsburgh
Polytechnic Institute of Brooklyn (*a*)
Princeton University
Purdue University
Rensselaer Polytechnic Institute
Rhode Island State College
Rice Institute
Rose Polytechnic Institute
Rutgers University
University of Santa Clara
South Dakota State College
South Dakota State School of Mines
Stanford University
Swarthmore College
Syracuse University
University of Tennessee
University of Texas
A. & M. College of Texas
Texas Technological College

Tufts College
Tulane University of Louisiana
Union College
University of Utah
University of Vermont
University of Virginia
Virginia Military Institute
Virginia Polytechnic Institute
Washington University
University of Washington
State College of Washington
West Virginia University
University of Wisconsin
Worcester Polytechnic Institute
Yale University

Electrical Engineering

University of Alabama
University of Arizona
University of Arkansas
Armour Institute of Technology
Brown University
Bucknell University
University of California
California Institute of Technology
Carnegie Institute of Technology (*a*)
Case School of Applied Science
University of Cincinnati
Clarkson College of Technology
Clemson Agricultural College
College of the City of New York (*a*)
University of Colorado
Columbia University (*b*)
Cooper Union Institute of Technology (*c*)
Cornell University
University of Delaware
University of Detroit
Drexel Institute
Duke University
University of Florida
Georgia School of Technology (*d*)
Harvard University (Electrical Engineering) (*e*)
Harvard University (Communication Engineering) (*e*)
Howard University
University of Idaho
University of Illinois
Iowa State College
State University of Iowa
Johns Hopkins University
University of Kansas
Kansas State College
Lafayette College
Lehigh University
Louisiana State University
University of Louisville
University of Maine

Marquette University
University of Maryland
Massachusetts Institute of Technology
University of Michigan
Michigan College of Mining and Technology
Michigan State College
University of Minnesota
University of Missouri
Missouri School of Mines and Metallurgy
Montana State College
University of Nebraska
University of Nevada
University of New Hampshire
University of New Mexico
New York University (*a*)
Newark College of Engineering
North Carolina State College
University of North Dakota
Norwich University
Ohio State University
University of Oklahoma
Oklahoma A. & M. College
Oregon State College (Excluding Business Option)
University of Pennsylvania
Pennsylvania State College
University of Pittsburgh
Polytechnic Institute of Brooklyn (*a*)
Princeton University
Purdue University
Rensselaer Polytechnic Institute
Rhode Island State College
Rice Institute
Rose Polytechnic Institute
Rutgers University
University of Santa Clara
South Dakota State College
South Dakota State School of Mines
Stanford University
Swarthmore College
Syracuse University
University of Tennessee
University of Texas
A. & M. College of Texas
Texas Technological College
Tufts College
Tulane University of Louisiana
Union College
University of Utah
University of Vermont
University of Virginia
Virginia Military Institute
Virginia Polytechnic Institute
Washington University
University of Washington
State College of Washington (Basic and Hydro-electric Options)

West Virginia University
University of Wisconsin
Worcester Polytechnic Institute
Yale University

Electrochemical Engineering

Massachusetts Institute of Technology
Pennsylvania State College

General Engineering (f)

University of Illinois
Iowa State College
University of Maine
Massachusetts Institute of Technology
Stevens Institute of Technology

Industrial Engineering

University of Alabama
Carnegie Institute of Technology (Management Engineering) (*a*)
Columbia University (*b*)
Cornell University (Administrative Engineering)
University of Florida
Harvard University (Engineering and Business Administration) (*e*)
Lafayette College (Administrative Engineering)
Lehigh University
Massachusetts Institute of Technology (Business and Engineering Administration)
Ohio State University
Oklahoma A. & M. College
Pennsylvania State College
University of Pittsburgh
Syracuse University (Administrative Engineering)
Virginia Polytechnic Institute
Washington University (Administrative Engineering)

Mechanical Engineering

University of Alabama
University of Arizona
University of Arkansas
Armour Institute of Technology
Brown University
Bucknell University
University of California
California Institute of Technology
Carnegie Institute of Technology (*a*)
Case School of Applied Science
University of Cincinnati
Clarkson College of Technology
Clemson Agricultural College
College of the City of New York (*a*)
University of Colorado
Columbia University (*b*)
Cooper Union Institute of Technology (*c*)
Cornell University
University of Delaware
University of Detroit
Drexel Institute
Duke University
University of Florida

Georgia School of Technology (*d*)
Harvard University (*e*)
Howard University
University of Idaho
University of Illinois
Iowa State College
State University of Iowa
Johns Hopkins University
University of Kansas
Kansas State College
Lafayette College
Lehigh University
Louisiana State University
University of Louisville
University of Maine
Marquette University
University of Maryland
Massachusetts Institute of Technology
University of Michigan
Michigan College of Mining and Technology
Michigan State College
University of Minnesota
University of Missouri
Montana State College
University of Nebraska
University of New Hampshire
University of New Mexico
New York University (*a*)
Newark College of Engineering
North Carolina State College
University of North Dakota
Ohio State University
University of Oklahoma
Oklahoma A. & M. College
Oregon State College (Excluding Business Option)
University of Pennsylvania
Pennsylvania State College
University of Pittsburgh
Polytechnic Institute of Brooklyn (*a*)
Princeton University
Purdue University
Rensselaer Polytechnic Institute
Rhode Island State College
Rice Institute
University of Rochester
Rose Polytechnic Institute
Rutgers University
University of Santa Clara
South Dakota State College
Stanford University
Swarthmore College
Syracuse University
University of Tennessee
University of Texas
A. & M. College of Texas

Texas Technological College
Tufts College
Tulane University of Louisiana
University of Utah
University of Vermont
University of Virginia
Virginia Polytechnic Institute
Washington University
University of Washington
State College of Washington (Basic Option)
West Virginia University
University of Wisconsin
Worcester Polytechnic Institute
Yale University

Metallurgical Engineering

University of California (Metallurgy)
Carnegie Institute of Technology (*a*)
Case School of Applied Science
Colorado School of Mines
Columbia University (*b*)
Harvard University (Physical Metallurgy) (*c*)
University of Illinois
University of Kentucky
Lafayette College
Lehigh University
Massachusetts Institute of Technology (Metallurgy)
University of Michigan
Michigan College of Mining and Technology
University of Minnesota
Missouri School of Mines and Metallurgy
Montana School of Mines
Ohio State University
University of Pittsburgh
South Dakota State School of Mines
Stanford University
University of Utah
University of Washington
State College of Washington
University of Wisconsin
Yale University (Metallurgy)

Mining Engineering

University of Alabama
University of Arizona
University of California
Colorado School of Mines (Mining Engineering)
Colorado School of Mines (Geological Engineering)
Columbia University (*b*)
University of Illinois
University of Kansas
University of Kentucky
Lafayette College
Lehigh University
Massachusetts Institute of Technology
Michigan College of Mining and Technology
University of Minnesota (Excluding Mining in Geology Option)

Missouri School of Mines and Metallurgy (Mine Engineering) (Excluding Mining Geology Option)
Montana School of Mines (Mining Engineering)
Montana School of Mines (Geological Engineering)
University of Nevada
University of North Dakota
Ohio State University (Mine Engineering)
University of Pittsburgh
South Dakota State School of Mines
Stanford University
University of Utah
University of Washington
State College of Washington (Excluding Mine Administration and Petroleum Engineering Options)
West Virginia University
University of Wisconsin

Naval Architecture and Marine Engineering

Massachusetts Institute of Technology
University of Michigan
Webb Institute of Naval Architecture

Petroleum Engineering

University of California
Colorado School of Mines
Louisiana State University
University of Minnesota
University of Oklahoma (Production Option)
University of Pittsburgh (Petroleum Engineering)
University of Pittsburgh (Petroleum Refining)
University of Southern California
Stanford University
University of Texas (Petroleum Production Engineering)
A. & M. College of Texas

Sanitary Engineering

Harvard University (*e*)
Massachusetts Institute of Technology (Sanitary Engineering)
Massachusetts Institute of Technology (Public Health Engineering)
Pennsylvania State College
Rutgers University

Explanatory Notes

(*a*) Accrediting applies to both the day and evening curricula.

(*b*) Accrediting applies to the four-year and five-year curricula leading to the Bachelor of Science degree.

(*c*) Accrediting applies to day curriculum only. Action on evening curriculum deferred pending granting of degrees.

(*d*) Accrediting applies to both regular and cooperative curricula.

(*e*) Accrediting applies only to curriculum as submitted to E. C. P. D. and upon completion of which a certificate is issued by Harvard University certifying that the student has pursued such a curriculum.

(*f*) The accrediting of a curriculum in general engineering implies satisfactory training in engineering sciences and in the basic subjects pertaining to several fields of engineering; it does not imply the accrediting, as separate curricula, of those component portions of the curriculum such as civil, mechanical or electrical engineering that are usually offered as complete professional curricula leading to degrees in these particular fields.

(*g*) All curricula in agricultural engineering which appear in this list have been provisionally accredited for a period of two years. The reason for this is twofold; in the first place it appears to E. C. P. D. that the final year of the four year programs fails to build, in adequate manner, upon the engineering basis laid in the first three years; secondly, it is the feeling of E. C. P. D. that curricula in agricultural engineering might more properly be given as options under one of the major engineering branches (*i.e.*, civil engineering, electrical engineering, or mechanical engineering).

(*h*) E. C. P. D. has not received from its sub-committee on Chemical Engineering a recommendation with respect to the evening curriculum in Chemical Engineering.

III. Committee Personnel

(*A*) *Committee on Engineering Schools*

The membership of the E. C. P. D. Committee on Engineering Schools is as follows:

Karl T. Compton, Massachusetts Institute of Technology, *Chairman*, representing American Institute of Electrical Engineers.

H. P. Hammond, Pennsylvania State College, *Vice Chairman*, representing Society for the Promotion of Engineering Education.

G. M. Butler, University of Arizona, representing American Institute of Mining and Metallurgical Engineers.

Ivan C. Crawford, University of Kansas, representing American Society of Civil Engineers.

Harry A. Curtis, Tennessee Valley Authority, representing American Institute of Chemical Engineers.

P. H. Daggett, Rutgers University, representing National Council of State Boards of Engineering Examiners.

A. A. Potter, Purdue University, representing American Society of Mechanical Engineers.

(*B*) *Committees of Inspection*

Following is a membership list of all delegatory committees of E. C. P. D.

American Society of Civil Engineers

G. W. Case, University of New Hampshire, Durham, N. H.
L. E. Conrad, Kansas State College, Manhattan, Kans.
H. S. Crocker, Cons. Engineer, Denver, Colo.
G. J. Davis, University of Alabama, Tuscaloosa, Ala.
Donald Derickson, Tulane University, New Orleans, La.
N. W. Dougherty, University of Tennessee, Knoxville, Tenn.
C. L. Eckel, University of Colorado, Boulder, Colo.
J. K. Finch, Columbia University, New York, N. Y.
A. J. Hammond, Cons. Engineer, Chicago, Ill.
E. E. Howard, Ash, Howard, Needles & Tammen, Kansas City, Mo.
Joseph Jacobs, Cons. Engineer, Seattle, Wash.
Anson Marston, Iowa State College, Ames, Iowa
Louis Mitchell, Syracuse University, Syracuse, N. Y.
C. A. Mockmore, Oregon State College, Corvallis, Ore.
J. P. H. Perry, Turner Construction Co., New York, N. Y.
Arthur Ridgeway, Equitable Bldg., Denver, Colo.
C. W. Sherman, Metcalf & Eddy, Boston, Mass.
R. B. Wiley, Purdue University, Lafayette, Ind.

American Institute of Mining and Metallurgical Engineers

A. C. Callen, University of Illinois, Urbana, Ill.
Jay A. Carpenter, Mackay School of Mines, Reno, Nev.
J. R. Cudworth, University of Alabama, Tuscaloosa, Ala.
D. J. Demorest, Ohio State University, Columbus, O.
C. H. Fulton, Missouri School of Mines, Rolla, Mo.
E. A. Holbrook, University of Pittsburgh, Pittsburgh, Pa.
Zay Jeffries, Cons. Engineer, Cleveland, Ohio
C. E. Lawall, West Virginia University, Morgantown, W. Va.
Robert S. Lewis, University of Utah, Salt Lake City, Utah
C. H. Mathewson, Yale University, New Haven, Conn.
T. T. Read, Columbia University, New York, N. Y.
Milnor Roberts, University of Washington, Seattle, Wash.
Francis A. Thomson, Montana State School of Mines, Butte, Mont.
G. B. Waterhouse, Massachusetts Institute of Technology, Cambridge, Mass.
C. M. Young, University of Kansas, Lawrence, Kans.

American Society of Mechanical Engineers

B. M. Brigman, University of Louisville, Louisville, Ky.
E. F. Church, Jr., Polytechnic Institute of Brooklyn, Brooklyn, N. Y.
A. J. Dickie, Pacific Marine Review, San Francisco, Calif.
S. W. Dudley, Yale University, New Haven, Conn.
S. B. Earle, Clemson Agricultural College, Clemson College, S. C.
J. H. Felgar, Univ. of Oklahoma, Norman, Okla.
J. W. Haney, University of Nebraska, Lincoln, Neb.
Dexter S. Kimball, Cornell University, Ithaca, N. Y.
F. W. Marquis, Ohio State University, Columbus, Ohio
D. B. Prentice, Rose Polytechnic Institute, Terre Haute, Ind.
R. A. Seaton, Kansas State College, Manhattan, Kans.
E. H. Tenney, Union Elec. Light & Power Co., St. Louis, Mo.
Eric Therkelsen, Montana State College, Bozeman, Mont.
H. R. Westcott, Westcott & Mapes, Inc., New Haven, Conn.
Baldwin M. Woods, University of California, Berkeley, Calif.

American Institute of Electrical Engineers

F. C. Bolton, Agri. & Mech. College of Texas, College Station, Texas
H. V. Carpenter, Washington State College, Pullman, Wash.
R. E. Doherty, Carnegie Institute of Technology, Pittsburgh, Pa.
A. M. Dudley, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
O. W. Eshbach, A. T. & T. Co., New York, N. Y.
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